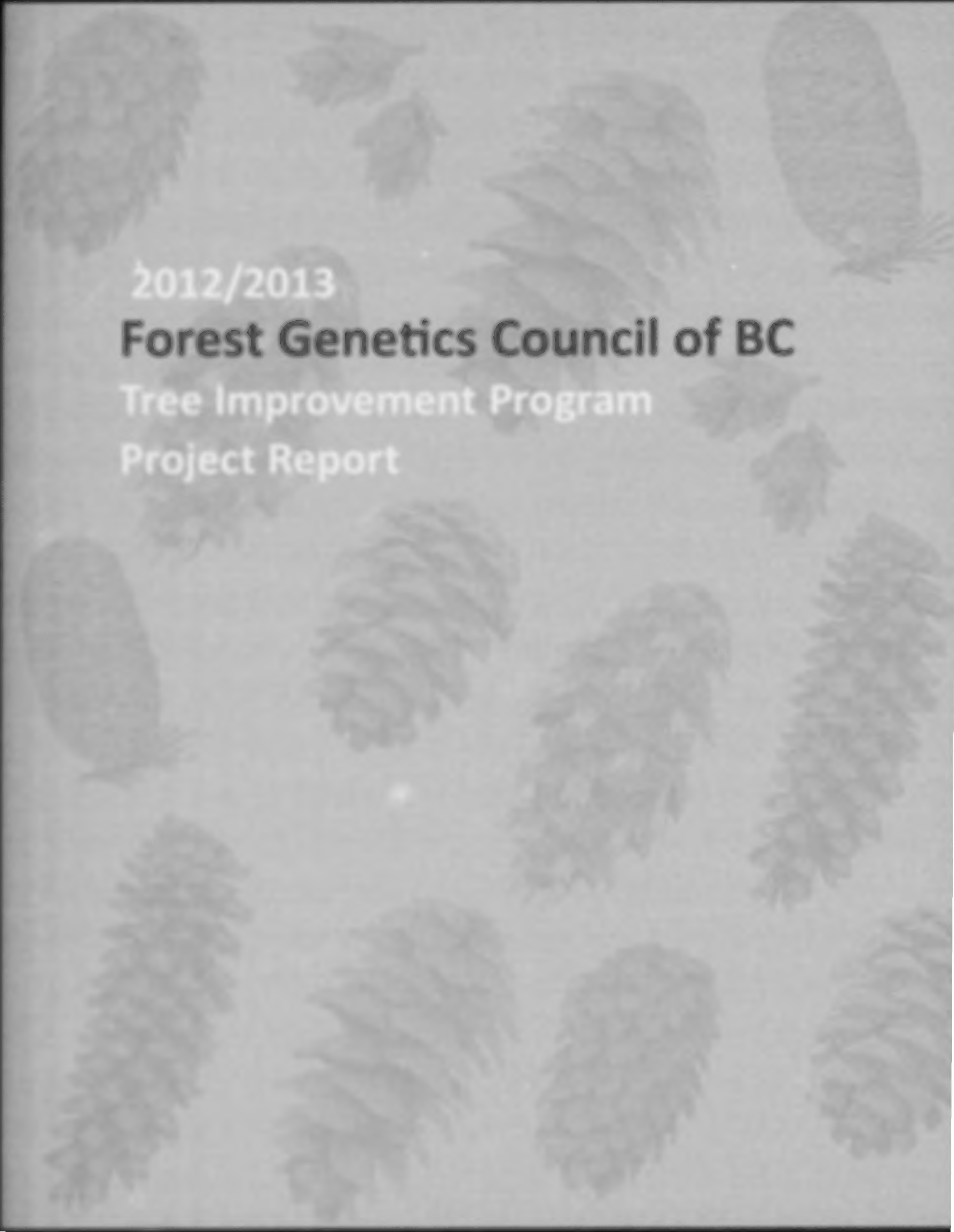

2012/2013

Forest Genetics Council of BC

Tree Improvement Program
Project Report

2012/2013

Forest Genetics Council of BC

Tree Improvement Program Project Report

Introduction and Acknowledgements

During the period of this report the Forest Genetics Council of BC (FGC) continued to lead activities related to forest genetic resource management (GRM) in BC. Business planning was completed for the allocation of Land Based Investment Strategy (LBIS) funding from the FLNRO. This planning also guides investments from licensees and other collaborators to ensure efficiency. Budgets and plans were published in an annual Business Plan and previous year's results were summarized and reported in the FGC Annual Report (http://www.fgcouncil.bc.ca/doc.html#FGCReport).

Broad performance indicators linked to the use and genetic gain of select seed are largely being met, however, it is evident that poorer-than-expected seed production from lodgepole pine seed orchards may prevent achievement of the objective for 75% class A seed use by 2014, as set out in Council's Strategic Plan (http://www.fgcouncil.bc.ca/StratPlan0914-Layout-Web-22Dec09.pdf). The challenges related to lodgepole pine seed production will be partially moderated by an expected reduction in seed demand as harvesting and planting levels drop in central BC. High planting levels have exceeded the capacity of pine orchards to provide needed seed, forcing the use of wild seed and lowering the overall percentage of select seed use. As planting drops, the percentage of seed from seed orchards is expected to rise. While this trend helps progress to a provincial objective, it will create new challenges for seed orchard businesses as sales and revenues drop relative to operational costs.

It is noteworthy that many seed planning units with investments in tree breeding and seed orchards are fully meeting expectations and are at or close to 100% orchard seed use for operational planting. These include Douglas-fir, redcedar, and hemlock in the maritime zone and most interior spruce and larch seed zones. Interior Douglas-fir seed supplies are rising and increasingly orchard seed is being used. Breeding programs and seed orchards providing genetically selected seed for these areas are a success story and are contributing to the long-term increase and stability of timber supply in BC.

Progress continues in other program areas. It's noteworthy that seed collection and storage work for genetic conservation purposes has now resulted in the secure storage of about 9,000 seedlots at the Provincial Tree Seed Center. In addition, scientific work and policy development continue to advance for a provincial system for climate-based seed transfer. This long-term work is supplemented by the AdapTree genomics project at the University of BC and its associated project linked to social, legal, and policy issues related to the movement of tree seed as a proactive means to mitigate against the impact of climate change on the health and productivity of provincial forests.

People remain the backbone of this provincial program. While much talent remains in both the public and private sector groups focused on GRM, succession is an ongoing issue. Fortunately, some new people have entered this type of work over the last few years and bring new ideas and energy. More, however, are needed before the main cohort of highly experienced people retire over the next 5 or so years. This has long been identified by the FGC as the primary challenge for the provincial GRM program. Solutions will continue to be developed, but the risk of losing key expertise is high.

I would like to sincerely thank members of Council and members of all technical committees for their ongoing efforts, and to acknowledge and thank all of the people within the MFLNRO and industry who willingly collaborate and work to make this program a success.

Jack Woods
Program Manager, Forest Genetics Council of BC
CEO, SelectSeed Ltd.

The Forest Genetics Council Co-chairs invite you to review the programs and projects described in this report and return any questions or comments to:

Tree Improvement Coordinator
Ministry of Forests, Lands and Natural Resource Operations (MFLNRO)
Tree Improvement Branch
PO Box 9518 Stn Prov Govt
Victoria, BC V8W 9C2

Further Tree Improvement information can be found at our web sites:

Forest Genetics Council	http://www.fgcouncil.bc.ca
MFLNRO, Tree Improvement Branch	http://www.for.gov.bc.ca/hti http://www.for.gov.bc.ca/hre/forgen/

BRITISH COLUMBIA
Ministry of
Forests, Lands and
Natural Resource Operations

FGC Forest Genetics Council
of British Columbia

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Tree Improvement in British Columbia

The Forest Genetics Council of British Columbia (FGC) is a multi-stakeholder group reporting to the provincial Chief Forester and representing the forest industry, Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), the Canadian Forest Service, and universities. Council's mandate is to champion forest genetic resource management (GRM) in British Columbia, to oversee strategic and business planning for the provincial Land Based Investment Strategy (LBIS) Tree Improvement Program, and to advise the province's Chief Forester on forest genetic resource management policies. FGC Technical Advisory Committees (TACs) provide technical and policy information to Council and contribute to the development of FGC plans and associated budgets.

Council's vision is that BC's forest genetic resources are diverse, resilient, and managed to provide multiple values for the benefit of present and future generations. This vision is supported by six objectives that are set out in Council's Strategic Plan for the period 2009 to 2014[*] and reported upon annually.

Annual business planning processes are designed to support achievement of the objectives, and the FGC Business Plan defines the annual set of activities and budgets needed to achieve objectives and realize the overall vision.

Forest genetic resource management is a co-operative effort in BC. In broad terms, the MFLNRO leads tree breeding activities and private companies contribute with progeny test locations. Orchard seed production is a collaborative effort between MFLNRO and the private sector. The MFLNRO, universities and consultants carry out research supporting operational GRM programs.

Various technical advisory committees reporting to the FGC facilitate collaboration on a variety of support issues, including genetic conservation, climate based seed transfer, orchard pest management, extension, and records management and decision support.

The Interior and Coastal Technical Advisory Committees (ITAC and CTAC) are the primary committees reporting to and informing the FGC. Members are drawn from people involved with GRM activities in BC, as well as operational forestry staff from forest companies or government agencies. The Chairs of the ITAC and CTAC sit as members of Council to facilitate communication and input between the policy and management perspective of Council and the more applied perspective of the TACs. Other technical advisory committees also advise the FGC, but are not directly linked through Council membership. These TACs include Genetic Conservation (GCTAC), Seed Transfer (STTAC), Extension (ETAC), cone and seed Pest Management (PMTAC), and Decision Support (DSAC).

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[*] http://www.fgcouncil.bc.ca/StratPlan0914-Layout-Web-22Dec09.pdf

LBIS – FGC Tree Improvement Subprograms

The Land Based Investment Strategy Tree Improvement Program (LBIS TIP) is structured to deliver the provincial strategy for forest genetic resource management developed by the Forest Genetics Council. There are eight subprograms:

- Genetic Conservation
- Tree Breeding
- Operational Tree Improvement Program (OTIP)
- Orchard Seed Supply ([illegible])
- Extension and Communication
- Genecology and Seed Transfer
- Genetic Resource Decision Support
- Seed Orchard Pest Management

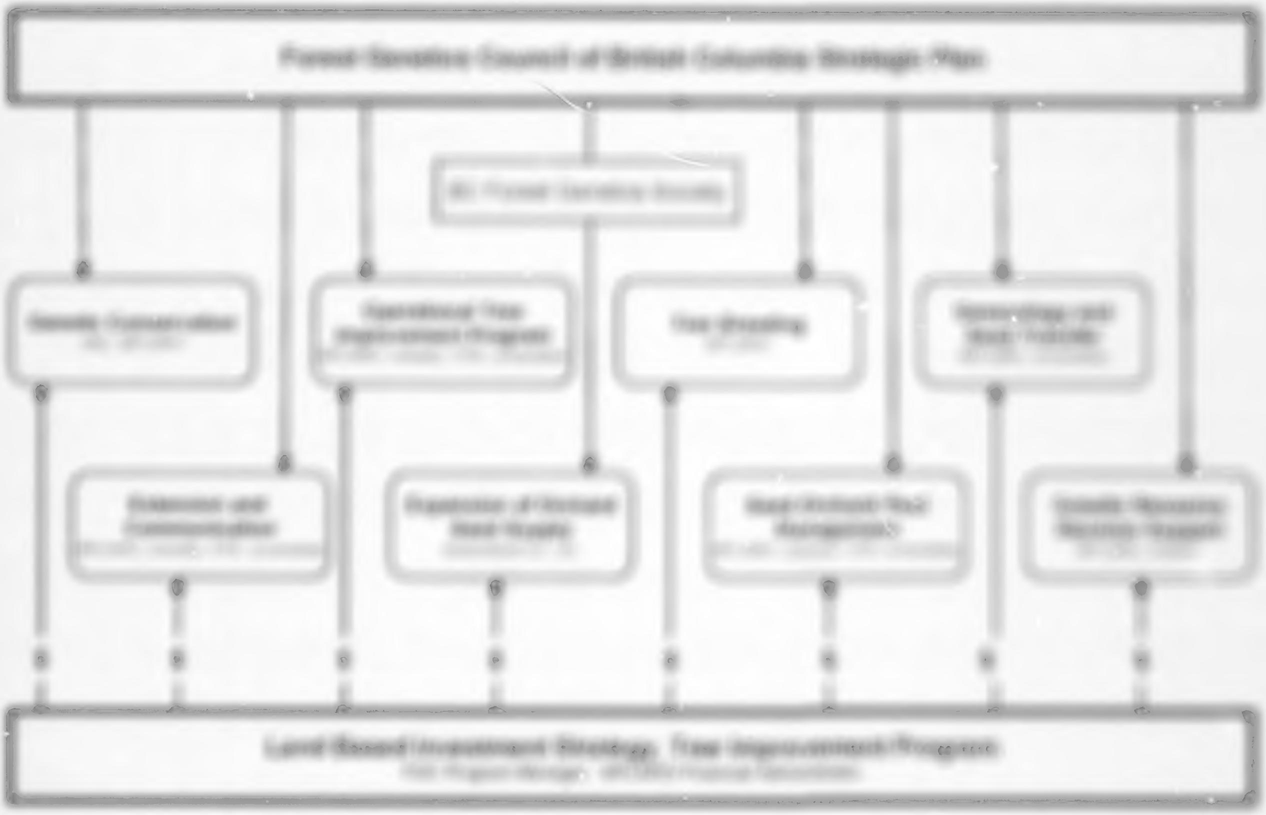
Forest Genetics Council of British Columbia Strategic Plan
BC Forest Genetics Society
Genetic Conservation
Operational Tree Improvement Program
Tree Breeding
Genecology and Seed Transfer
Extension and Communication
Expansion of Orchard Seed Supply
Seed Orchard Pest Management
Genetic Resource Decision Support
Land Based Investment Strategy, Tree Improvement Program

Figure 1. Relationship between FGC Strategic Plan, LBIS TIP and participants in various forest genetic resource management areas.

1.0 Expansion of Orchard Seed Supply Subprogram (SelectSeed Co. Ltd.)

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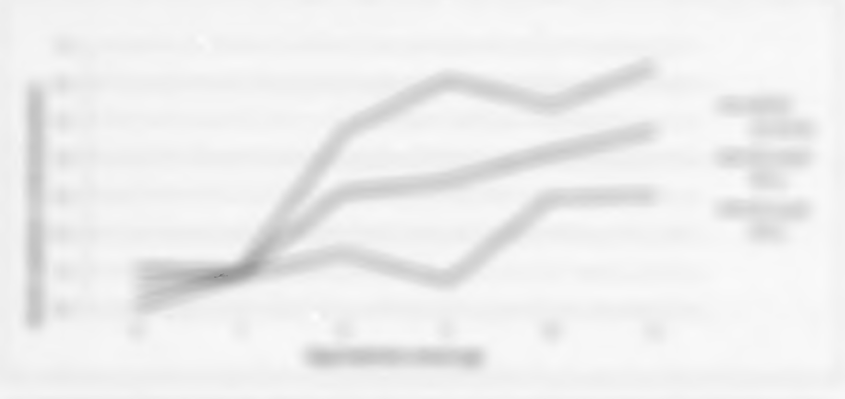

[illegible]

[illegible] Genetic Conservation Technical Advisory Committee (GCTAC)

[illegible]

[illegible]

[illegible] Centre for Forest Conservation Genetics (CFCG), University of BC

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[illegible]

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thesis of Jonathan Degner). The whitebark pine elevational transect experiment planted under the Peak to Peak guideline was also re-measured in 2012.

Finally, the CFGC assumed responsibility for the BC Big Tree Registry in 2013, and started developing a new website and online database for the registry under the guidance of the BC Big Tree Committee. The new registry and website will be launched by this committee in cooperation with UBC in the spring of 2014.

2.2 Tree Improvement Branch Conservation Activities

Charlie Cartwright

Conservation Catalogue

Genetic conservation requires sound inventories for species of concern in order to be effective. For trees in BC an overview catalogue has been completed, followed by a detailed report on the major timber trees with a third document covering tree species less commonly harvested in development. Logically a last catalogue in the series would cover the status of trees rarely utilized or never harvested. Since the regeneration of these is not managed, they will be of greatest interest for conservation. Through the development of these reports, some inadequacies of our approach to inventories have become apparent. The new strategic plan for the Genetic Conservation Technical Advisory Committee (GCTAC) will need to address these shortcomings of our catalogue methodology.

Ex Situ Seed Collection

Seed collections for ex situ reserves are continuing, and progress was fair in the current year given relatively poor cone crops. Highlights were procurement of seed from 3 interior provenances of grand fir along with 2 populations of whitebark pine and one of limber pine. As well, our collectors were able to obtain most of the western yew required along with bitter cherry, water birch, alpine larch, Rocky Mountain and seaside juniper plus one provenance of Pacific crabapple. Collections will be continued in the new fiscal year.

Whitebark Pine

Due to catastrophic population declines across much of its range (much of which is in British Columbia), whitebark pine was declared "endangered" under the Federal Species at Risk Act of 2002. This action requires the development of a recovery plan, but the act also specifies in several clauses that it is incumbent on the provinces to support the national plan. For this reason several of our staff attended sessions for the purpose of assisting with drafting the BC document. In terms of concrete action to address the causes of mortality, field trials screening for resistance to white pine blister rust were first planned in early 2012 through GCTAC. During the year, the approach was refined through 3 separate drafts edited by committee members, seed from almost 250 prospective parent trees from across the range was amassed, arrangements for stratification were made and a contract for growing the plants was readied for bid. However, it was uncertain that there would be sufficient staffing in the future to carry the project through so it was postponed.

Figure 3. Dying whitebark pine in the Rocky Mountains illustrating population decline.

Dave Kolotelo

Seed Bank Management

This year more emphasis was placed on whitebark pine in terms of assuring seeds are dry enough for long term storage, assessing seed sample quality via x-rays for the upcoming field trial and helping to create a whitebark pine inventory database including seed attributes and origin including an assessment of parent tree health. Plans are underway to use water activity (the equilibrium moisture content determination) as a method of assessing whether seeds are dry enough for long-term storage. This is seen as a perfect use of this technology due to its ability to non-destructively assess the small sample sizes we generally have. Thanks should be extended to programs in France and Québec which have performed much of the method development and assessment work with a wide range of tree species, including Pli and Cw.

3.0 Tree Breeding

3.1 Coastal Douglas-fir Program

Michael Stoehr, Keith Bird and Lisa Hayton

Age 11 measurements of Series 2 of advanced generation breeding (EP708.22) were made and data analysed. The four GCA test sites (Hillcrest (Mesachie Lake), Big Tree (Sayward), Jordan River, and Museum (Port Alberni)) provided excellent estimates for parents, while the two full-sib sites (Jordan River, North Arm) provided estimates for forward selections. A total of 39 forward selections were made with an average bv of 17. Using an optimization algorithm to balance relatedness and gain, the seven identified forward selections to be included in the orchard have an average bv of 28. Together with the 9 genotypes selected in Series 1 for orchard deployment, the average orchard genetic worth (GW) is 29. For all selections, stem form and wood density were secondary selection criteria. The breeding population selected from the 8 sublines tested consists of 52 (8x6) selections to be grouped into the same 8 sublines for further breeding and testing. All of the selected genotypes have been grafted this spring and will be transplanted in the fall 2013. Test trees on Series 1 test sites have been permanently tagged and pruned to 2 m.

The wood density evaluation on two of the GCA sites of Series 2 was done using increment cores and the Resistograph. We wanted to assess first, wood density and secondly, the correlation between Resistograph reading and core-derived wood densities. In Table 2, the results of this evaluation is shown. Resistograph readings yield the same results and are much more economical to obtain. Heritabilities between the two estimation methods were similar for individual sites but the combined site analysis using Resistograph data showed higher GxE interactions, lowering the heritability of Resistograph-derived wood density estimates. However, the genetic correlation across sites for "two" traits was 0.91. Thus, Resistograph can be used for this type of evaluation.

Site	Core-based Density		Resistograph Amplitude		Type A r_g (SE)
	Family VC (SE)	Heritability (SE)	Family VC (SE)	Heritability (SE)	
Hillcrest	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Jordan River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Combined	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Type B r_g	[illegible]		[illegible]		

[1] VC is the variance component, SE is the standard error of the estimate

[2] Type A genetic correlation is the genetic correlation between two traits

[3] Type B genetic correlation is the genetic correlation of additive genetic variances between sites

Table 2. Genetic parameters for wood density (based on cores) and resistograph amplitude values (averaged over dbh) obtained from two GCA polymix tests of coastal Douglas-fir taken at age 12 years from seed. Number of families assessed is 60.

Inbreeding and its effects on performance is always a concern for tree breeders. For this reason, a test was established in 1987 with three levels of inbreeding (half-sib matings (f=0.125), full-sib matings and parent-offspring matings (f=0.25) and selfing (f=0.5), where "f" is the inbreeding coefficient). After 26 years, the effects of inbreeding are still significant, with survival suffering the highest inbreeding depression and wood density the lowest. Figure 3 shows the percent inbreeding depression for each level of inbreeding tested and trait assessed combined over two test sites (Langley and North Arm). The practical implications for information with orchard seed are that the probability of full-sib matings in coastal Douglas-fir seed orchards are very small (as the number of related individuals in an orchard is controlled) and if it does lead to filled seed, these inbreds will be eliminated by competition (self-thinning) prior to harvest.

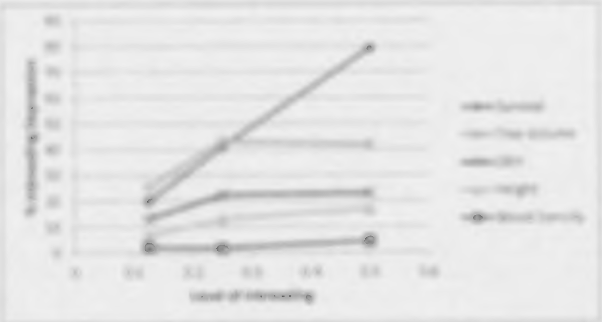

Figure 3. Amount of inbreeding depression in coastal Douglas-fir in survival, growth traits and wood density as affected by levels of inbreeding. Data were averaged over two coastal test sites and taken at age 26.

Our work to assess the impacts of Swiss Needle Cast (SNC) is continuing with cooperation from David Noshad. SNC is present in Jordan River (Plate 3) and we are in the process of developing an *in vitro* screening method for this disease. Our test population at Research Branch Laboratory raised beds serves as a test population for screening. These trees were also to determine levels of secondary metabolite variation (phenolics and terpenes) in these full-sib families. Preliminary analysis showed that up to 50% of the total variation levels is due to families. After screening the families for disease resistance, putative relationships to the secondary metabolites will be explored. Seedlings from the same 40 families are also currently "naturally" screened by growing underneath known infected trees in Jordan River.

Publications

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Kranabetter, J.M., M.U. Stoehr, and G.A. O'Neill. 2012. Specificity of ectomycorrhizal fungal communities with local populations of Douglas-fir and implications for assisted migration. Ecological Appl. 22:550-560.

El-Kassaby, Y.A., S. Mansfield, F. Isik, and M. Stoehr. 2011. In situ wood quality assessment in Douglas-fir. Tree Genetics Genomes 7:553-561.

Stoehr, M., J. Woods, and A. Yanchuk. 2011. Selection Approaches in High-Elevation Coastal Douglas-fir in The Presence of GxE Interactions. Silvae Genetica 60(2):79-84.

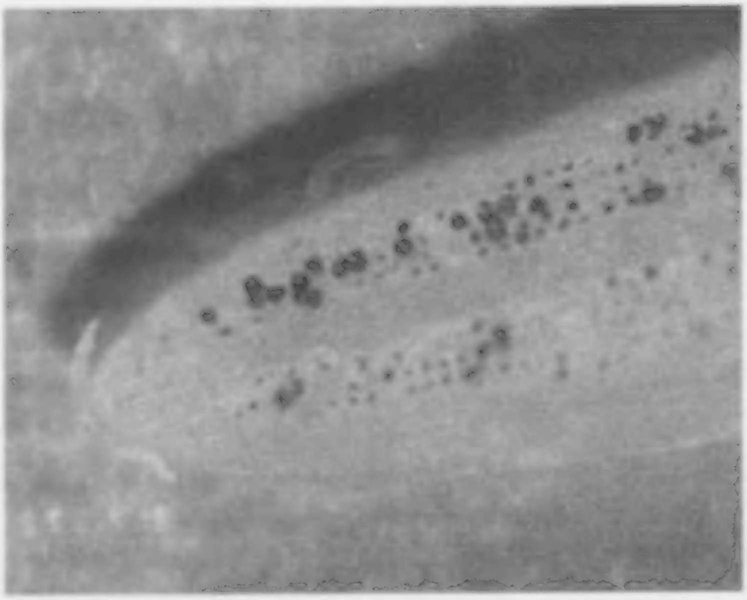

Plate 3. Underside of infected Douglas-fir needle with Swiss Needle Cast. The fruiting bodies (Pseudothecia) block the stomata, preventing gas exchange and then ultimately leading to needle death. (Photo David Noshad)

3.2 Western Hemlock Forest Genetics Program

Charlie Cartwright

More western hemlock is harvested on the BC Coast than any other species, but areas where it is felled are restocked through natural regeneration with less than a quarter of cut blocks being planted. Due to the limited demand for seed, the Hemlock Forest Genetics Program of Tree Improvement Branch restricts activities to securing assets (field installations) in which investments were made in previous years. Final measurements are being taken and maintenance towards mothballing of sites is ongoing in case they could be of some use in the future. It was anticipated that 8 progeny trials would be weeded this year, but instead 5 were done more intensively. Age 10 years data were collected from diallel tests and 2 realized gain trials were assessed, one for height and diameter age 20 years and the other for age 15 years. Based on the data collected in previous years, 37 clones were grafted for inclusion in clonebanks as forward selections; as well, 11 backward selections were also processed with the goal of securing all material from the Hemlock Tree Improvement Co-operative to which the province of BC is entitled, particularly trees from American sources. For the High Elevation Maritime, (SPU 24), 4 trials were maintained as planned but measurements were postponed; consequences of delaying measurements for the installations at higher elevations are less substantial due to the slower growth rates.

3.3 True Fir Forest Genetics Program

Charlie Cartwright

The true firs are minor timber species that are generally planted for ecological reasons or to foster stand resilience through species richness. The various *Abies* species have exceptional growth in particular types of sites, equaling or exceeding the performance of species more usually planted. The forest genetics program for true firs focuses on provenance testing which deploys seedlings from sources across the species' range to test sites established in areas where they grow in our province. Periodically, (about every 5 years), the trials are measured to evaluate their level of adaptation at the various test sites. From this, limits to the distance seed can be safely transferred can be derived, fast growing populations can be identified for seed collection (B+ seed), and effects of climate change for the species may be predicted.

With Pacific silver as well as sub-alpine fir, programs have only been undertaken in the last 10 years, so there are numerous treatments required on these younger installations. Maintenance was planned and carried out on 2 Pacific silver fir test sites, with measurements planned on 8 trials, though only 6 could be done due to an early snow fall. For sub-alpine fir maintenance was necessary on 11 trials while plans had listed only 8 installations to be brushed; the extra work was carried out with savings from other operations. One was measured, although that was not originally anticipated; its close proximity to a Pacific silver fir site being treated made this action attractive financially. In general the test sites are in good shape, though the high elevation locations have been slow to get past brush problems.

Grand fir and noble fir trials were established decades ago so less attention was required. 4 grand fir test sites had minor maintenance performed and scion material was collected at 2 of them. Grafting is being undertaken to represent the species' coastal range for gene conservation purposes, but care is taken to include the most vigorous populations in case some future use arises. Scion from Interior BC sources was also collected in the wild under the auspices of the GCTAC to complete the conservation effort. For noble fir, measurement of 5 of the 30 year old tests was planned, but no bids were received on the issue of an Invitation to Quote, and it was too late in the year to re-issue. Minor maintenance was undertaken, and the data collection postponed a year.

3.4 Western Redcedar Breeding Program

John Russell and Craig Ferguson

Our objective for the western redcedar breeding program is to develop a durable advanced generation population with potential cross resistance, or at least positive genetic correlations among resistance traits. Developing breeding populations that are resilient to multiple pests may not only give protection against the current target pests but potentially against future unknown ones. Growth and cedar leaf blight (CLB) intensity are significantly correlated, and selections for increased volume production and CLB resistance are easily achieved. Genetic correlations between secondary extractives in the foliage and growth rate, and secondary extractives in heartwood and the foliage, although not strong, are positively low to moderate, allowing us some good potential for independent culling in future selections. Although this is certainly a simplistic measure and assessment of complex chemical pathways, it does give us a potential indication that there is minimal competition in chemical resources between foliage and heartwood extractives.

The first generation improvement program focussed mainly on selection for growth with some emphasis on heartwood durability through enhanced secondary extractives. The deer resistance program, which was developed after the other traits were already under selection, has been directed at elevating foliage monoterpene concentrations. This was achieved through rapid generation turnover, high selection intensity and early greenhouse testing. There was minimal information from the other populations to incorporate multiple trait selection. We currently have no information on CLB resistance mechanisms but as in many leaf disease studies, foliar monoterpenes have been implicated.

Because of the partial confounding of population with selection objectives in the first generation of screening, we are currently establishing clonal trials with a combined multi-trait objective in each of the growth/CLB and the deer resistance populations. For the growth/CLB traits, advanced generation matings from backward selections have been completed for the first four series of polycross testing (there are a total of seven). Seedlings from approximately 150 F1 families were sampled for foliage monoterpenes in the greenhouse winter 2011, and high monoterpene selections have been cloned through rooting. These clones have been bulked-up to produce enough cutting material for clonal testing in 2014 for growth/CLB resistance across a number of environments. A second set of 150 F1 families were sown in 2012 and selection for monoterpenes and bulking up for clonal trials has occurred in this population as well.

For the deer resistance population, one-year-old seedlings from second generation full-sib breeding have already been tested for foliar monoterpenes and forward selections cloned for production hedges. Approximately 60 of these deer resistant clones were established in four environments conducive to good growth (two in Powell River) and cedar leaf blight (two on north Vancouver Island). Another set will be established in 2014.

Selections for advanced generation breeding will be separated into partial diallels grouped by traits, and matings performed within and between groups with assortative mating within groups. In order to achieve an effective population size of around 100, the final population will be composed of: 1) 50 3rd generation forward selections from the deer resistant population further clonally selected for growth and CLB resistance; 2) 50 first generation parental selections based on clonal values for total heartwood extractive content with selections removed with poor parental volume breeding values and foliar monoterpene parental clonal values (independent selection), and; 3) 50 2nd generation forward selections for volume further selected for deer resistance. It will most likely not be necessary to include parents selected primarily for CLB resistance since all volume selections will be resistant to CLB and the deer population will be further tested for resistance. Currently, mechanisms for CLB resistance are unknown but being researched. It may be appropriate to make additional selections based on future potential resistance mechanisms.

Deer resistant seedlots and veglots are currently being made available to industry on a limited basis for operational deployment trials. The first two sets were grown at Sylvan Vale nursery and planted out on central Vancouver Island in cooperation with TimberWest in 2011 and Western Forest Products in 2012. These plantings will be monitored over the next few years to determine if browsing is reduced with mixtures of resistant seedlings and rooted cuttings. Preliminary results have shown that high terpene rooted cuttings are more resistant to browse than comparable seedlings.

Two new western interior western redcedar provenance trials were established in the interior in spring 2012 in the northern ICH near Hazelton. Seed has been sown and sites selected for three more trials in the southern ICH near Salmo and Christina Lake.

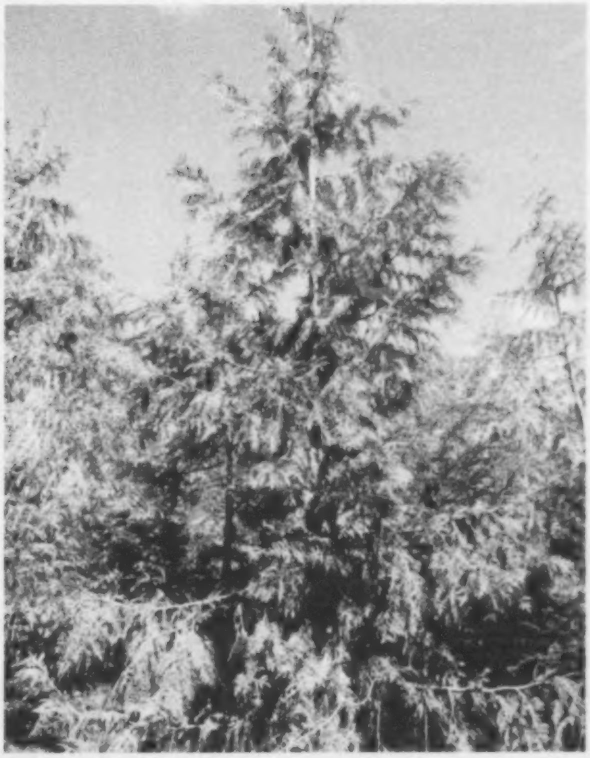

Plate 4. Local Kispiox tree free of cedar leaf blight at 15 year old western redcedar provenance trial near Kispiox, northern ICH.

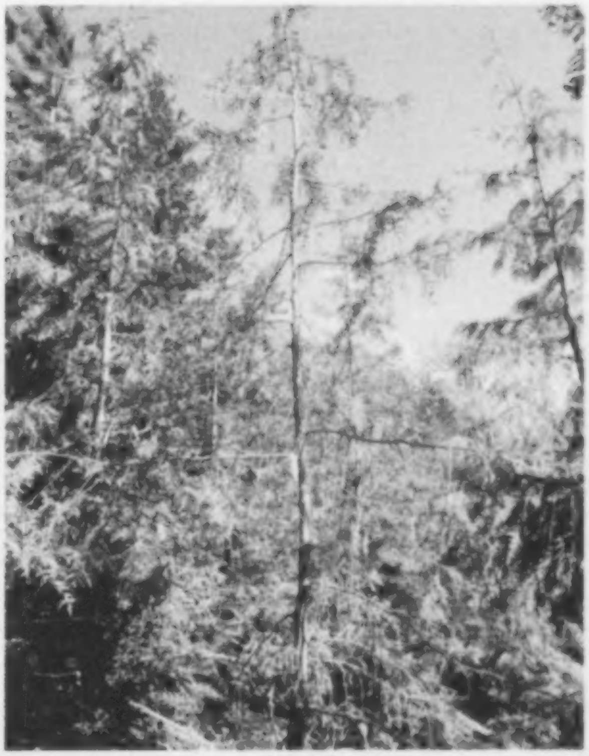

Plate 5. Southern interior tree with loss of branches and poorer diameter and height growth from severe cedar leaf blight at 15 year old western redcedar provenance trial near Kispiox, northern ICH.

3.5 Yellow Cypress Breeding Program

John Russell and Craig Ferguson

This program is currently focussing on maintenance and measurements of the clonal full-sib field trials. A select clonal population with a genetic gain of 20% volume has been established with serial propagated donors in greenhouses at Cowichan Lake Research Station (CLRS). This elite veglot has the potential to be 35% greater in early height as compared to wildstand seedlots across a wide range of ecosystems within the yellow cypress maritime SPU. In addition, approximately 100 foward clonal selections based on growth and form will be established at CLRS for archiving and future advanced generation breeding.

Twenty year measurements from the range-wide yellow cypress provenance trial were collected in 2012.

3.6 Coastal Broadleaf Species Genetics Program

Chang-Yi Xie, Lisa Hayton and Keith Bird

Red Alder

Range-wide provenance-progeny test

Preparation for a range-wide provenance-progeny testing is underway. Twenty four natural populations ranging from northern British Columbia to California were sampled (Plate 6) and seeds from 10 well-spaced mature trees were collected in each population.

Google earth

Plate 6. Locations of the sampled 24 natural populations.

About 15,000 seedlings are growing in the greenhouse (Plate 7) and will be ready for planting in the spring of 2014.

Test plantations will be established in the spring of 2014 at 9 sites that were selected based on their geographic locations, elevation distribution, BEC zones and site conditions. Field layout has been completed.

Plate 7. Red alder seedlings of the 24 populations growing in greenhouse at the Cowichan Lake Research Station.

First-Generation Red Alder Seed Orchard

A seed orchard has been established at Saanich Seed Orchard. It consists of 19 clones with 5-6 ramets each. Those 19 clones are forward selections made from the Bowser provenance-progeny test trial at test age 10 years. The genetic worth of this seed orchard is 28.

Plate 8. Red alder seed orchard established at Saanich Seed Orchard.

Big-leaf Maple

Trees on all 3 sites are doing well (Plate 9). Brushing has been completed and the second assessment will be completed by the end of 2013 fiscal year.

Plate 9: Four year big-leaf maple trial at Powell River site

Black Cottonwood

A total of 108 superior clones were selected based on 4-year performance at Harrison site and cuttings were collected from UBC where no infection of *Septoria musiva* has been noticed. Cuttings are being rooted at CLRS and will be planted at Saanich Seed Orchard soon.

Publications

Cappa, E. P., M. U. Stoehr, C-Y. Xie, and A. D. Yanchuk. 2013. Application of joint modeling of competition effects and environmental heterogeneity in Douglas-Fir trials using an individual-tree mixed model and Bayesian inference. IUFRO Cappa etal 2013 V1.7.ppt.

Xie, C-Y., M. R. Carlson and C. C. Ying. 2012. Ecotypic mode of regional differentiation of black cottonwood (*Populus trichocarpa*) due to restricted gene migration: further evidence from a field test on the northern coast of British Columbia. Can. J. For. Res. 42: 400-425.

3.7 Coastal Western White Pine

Nicholas Ukrainetz and Vicky Berger

The coastal western white pine breeding program has successfully incorporated local tested material with tested material from Oregon and Washington. After many years of collaboration with industry and the Canadian Forest Service, a formal F1 breeding program was initiated to take advantage of information gathered about local sources and families. Great effort was made to find the original parent tree selections in natural stands for breeding and pollen collection. The natural stand parent trees were ranked based on screening data and crossed to create a population of F1 progeny. Using collaborations with researchers in the United States, several control crossed families were acquired for testing in BC. The progeny of BC and US origins were deployed in 3 series of field trials on Vancouver Island, Texada Island and the Sunshine Coast; the seed for a fourth series of F1 progeny tests is also available. These progeny tests will be a source of resistant and tolerant material for current and future seed orchards on the coast.

Height measurements and rust surveys were conducted at three F1 progeny test sites that were planted in 2004 (Sahat Main, Kelly Creek and the Sechelt Canfor site). Some "selfs" (crosses made by self-pollinating an individual) were included in this test series. These selfs showed very good resistance to blister rust which suggests the possibility of recessive genes influencing quantitative resistance (non-major gene resistance). Unfortunately, selfs shows high inbreeding depression for growth. Data from F1 field sites have been used in the past 2 years to make forward selections which will be incorporated into current seed orchards for seed production and will be archived for future use in the breeding program. In 2012, 56 genotypes were selected which included several provenance selections, selections from a series of US diallels, and several trees with major gene resistance (MGR). In 2013, a further 38 trees were selected from 3 F1 progeny test sites. Site inspections for maintenance requirements were conducted on 6 sites. Only 1 site required further maintenance and tags were checked on all measured sites.

3.8 Interior Douglas-fir Tree Breeding Program

Barry Jaquish, Val Ashley, Charlie Phillips and Bonnie Hooge

The BC Interior Douglas-fir tree breeding program began in 1982 with the objective of producing improved and genetically diverse seed for planting stock on productive forest lands in south-central B.C. Within this wide-ranging and ecologically diverse land base, six seed planning units (SPUs) were delineated for tree improvement. The first cycle of breeding in each SPU was based on: 1) phenotypic selection in wild stands, 2) establishment of grafted breeding orchards and clone banks, 3) progeny testing using open-pollinated (OP) seed collected from wild stand trees, 4) delayed clonal seed orchards established using backward selection based on early progeny test results, and 5) controlled mating to produce pedigree material for second-generation selection. The breeding goal is to improve traits related to tree size (height, diameter and volume) while maintaining wood relative density near old growth values. Moreover, the recent discovery of resistance to Armillaria root disease in Interior Douglas-fir suggests that resistance to Armillaria could become an important trait of interest. The first-generation progeny testing program includes 1,466 OP families and 31 test sites across the six SPUs.

Seed orchards were established for each SPU in the north Okanagan in the early 1990s and are starting to come into production. In spring 2013, approximately 4 million of the 12.8 million Interior Douglas-fir seedlings planted in B.C. came from seed orchards. In 2010, selected parent trees from southern SPUs were identified to establish new 1.5 generation seed orchards for the Thompson Okanagan high and low elevation SPUs. The Thompson Okanagan region was excluded in the program's early stages because of low site productivity; however, recent increases in planting numbers combined with severe seed shortages for the area necessitate the establishment of orchards for these lands.

The second-generation crossing program focuses on the Nelson SPU and includes selected parents from the old West Kootenay, Shuswap Adams and Mica regions. Moreover, since inter-varietal (coastal x interior Douglas-fir) hybrids have shown to be hardy and fast growing in the Nelson low elevation zone, the Nelson second-generation breeding population has been augmented with 10 high breeding value parents from the BC coastal breeding program and 10 forward selections from superior Submaritime provenances in the Trinity Valley range-wide Interior Douglas-fir provenance test.

In spring 2012, 111 controlled crosses were completed in all of the Douglas-fir SPUs and 248 pollen lots were collected, processed and stored for future breeding. Controlled crossing for the Nelson SPU is about 90 percent complete. In fall 2012, maintenance and measurements were completed on three 25-year-old progeny test sites in the Nelson high elevation SPU. Data analyses are in progress. New breeding values for parents from the Prince George, Mt Robson and Cariboo Transition/Quesnel Lakes SPUs were released in spring 2013.

In addition to the progeny test measurements, three 25-year-old sites in the Nass Skeena Transition Douglas-fir adaptation trial and three 3-year-old sites in the Peace River adaptation trial were maintained and measured. In the Nass Skeena trial, seed sources from the northern limits of Douglas-fir's distribution (Mt Robson, Prince George and Quesnel Lake zones) were twice as tall as seedlings from the southern coastal zones (mean ht25 = 9.0 m vs 4.5 m). Survival was 80 % for the northern sources and 40% for the coastal sources.

Photo: [illegible] years old Douglas-fir from the [illegible] seed planning zone growing on the [illegible] test site north of [illegible], BC. The test site is located in the [illegible] zone, far outside the natural range of Douglas-fir.

3.9 Interior Spruce Tree Breeding Program

Barry Jaquish, [illegible], Gisele Phillips and Bonnie Hooge

Interior spruce is the oldest tree improvement program in the BC Interior. Genetic testing and parent tree selection began in the late 1960s and expanded rapidly through the 1970s and 80s. Phase one of the program focused on three ecologically and geographically unique regions: Prince George, Bulkley Valley and East Kootenay. Phase two began in the mid-1970s and covered all the remaining geographic regions where Interior spruce was commercially and ecologically important. The program has progressed to the point where [illegible] percent of the [illegible] million seedlings planted in 2012 came from improved first-generation seed orchards. Full-sib 2nd-generation progeny tests are in place for the Prince George, East Kootenay and [illegible] SPUs. In the Prince George Series 1 program, [illegible] 2nd-generation forward selections have been grafted and established in clone banks and breeding orchards. In the East Kootenay SPU, [illegible] 2nd-generation forward selections were made in 2009 based on 10-year measurements. Grafting was completed in early spring 2010 and a new breeding orchard was planted at Kalamalka in spring 2012. Breeding for 2nd-generation selection is now focussing on the Nelson low and mid-elevation SPUs. Unfortunately the 2012 spruce flower crop was poor and only [illegible] crosses were made in the Nelson and Thompson Okanagan SPUs. Forty-year measurements were completed on two ([illegible] and Quesnel) Prince George SPU test sites. Additional test plantation maintenance and measurement included: three sites in the ten-year-old Prince George genecology test and six sites in the 15-year-old interior spruce somatic seedling field trials. Seedlings from all of the parents in seed orchard [illegible] (Vernon Seed Orchard Company) were planted in raised beds at Kalamalka for further screening for weevil resistance. In spring 2013, [illegible] full-sib seedlots from the Thompson Okanagan SPU were sown for planting in 2nd generation test sites.

3.10 Western Larch Tree Breeding Program

Barry Jaquish, [illegible]

In 2012, approximately [illegible] million western larch seedlings were planted in B.C., [illegible] percent of which originated from seed orchards. In the second-generation crossing program, [illegible] crosses were completed and [illegible] was collected and stored for future sowing. Second-generation crossing in the East Kootenay and Nelson SPUs is now [illegible] and [illegible] complete, respectively. [illegible] maintenance and measurement was completed on the Nelson SPU [illegible] progeny tests. Data analyses are ongoing.

Publications

[illegible] G.E. Rehfeldt [illegible] B. Jaquish. 2012. [illegible] climate change scenarios: implications for [illegible]

Leites, L., G.E. Rehfeldt, A.P. Robinson, N. Crookston and B. Jaquish. 2012. Possibilities and limitations of using provenance tests to infer forest species growth responses to climate change. Natural Resource Modeling 25(3):409-433.

[illegible] B. White, B. Jaquish [illegible] 2012. [illegible] the genetic architecture for growth and wood [illegible] spruce. [illegible]

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4.0 Seed Transfer Technical Advisory Committee

Lee Charleson

The Seed Transfer Technical Advisory Committee (STTAC) continues its work developing priorities in genecology research, setting project proposals and providing budget recommendations to FGC for genecology and seed transfer research.

Funding of ministry genecology projects is done in accordance to the Genetics Section STTAC Strategy, 2011-2016, dated January 10, 2012. For genecology research outside of ministry Forest Genetics Section, a call for proposals is administered each year. The call supports FGC strategic objectives and provincial seed transfer policy development.

Genecology projects are reported in several sections of this document. For specific project information refer to the following sections: Centre for Forest Conservation Genetics and Breeding Reports.

4.1 Assisted Migration Adaptation Trial (AMAT)

Greg O'Neill, Vicky Berger, Nicholas Ukrainetz, and Michael Carlson

The AMAT (http://www.for.gov.bc.ca/hre/forgen/interior/AMAT.htm) is a long-term multi-species field trial intended to provide a better understanding of tree species' climate adaptation. The trial involves 49 seed sources (mostly orchard seedlots) from 15 species native to western North America planted at 48 test sites in BC, Alb, Yukon, and neighbouring US states. The final 12 test sites were established in spring 2012. Site climate is recorded continuously and survival, growth and health will be assessed every 5 years beginning in fall 2013. Relationships of seedlot survival, growth and health with plantation climate will be developed enabling identification of the seed sources most likely to be best adapted to current and future climates. The information will be used to revise BC's species and seed source selection guidelines, helping to ensure maximum health and productivity of BC's planted forests well into the future.

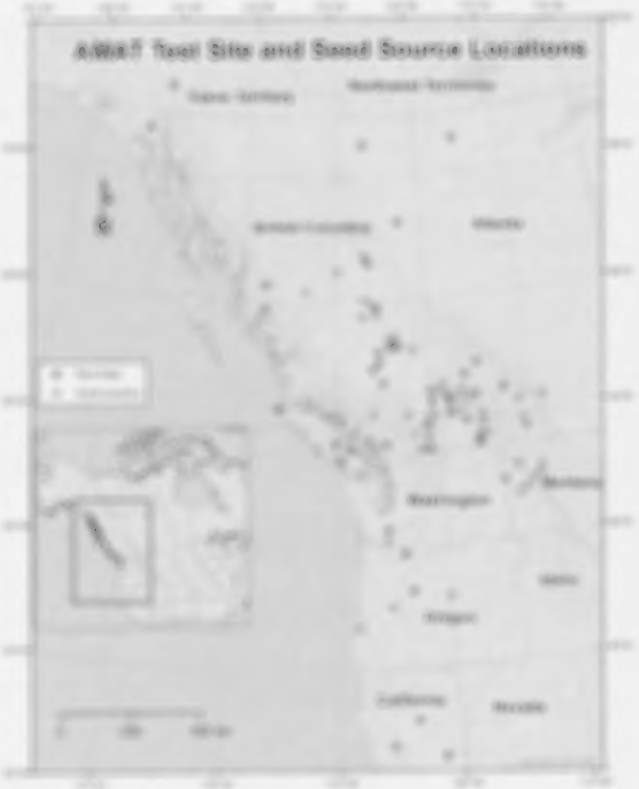


Figure 18. AMAT test site and seed source locations.

4.2 Interior Spruce Genecology/Climate Change Trial

Barry Jaquish and Greg O'Neill

A large interior spruce climate change/genecology field trial established in 2005 is beginning to provide valuable information that will guide seedlot selection for interior spruce. The trial consists of 128 seedlots (99 wildstand, 29 orchard) from BC, AB and neighbouring states and territories tested at 17 locations in BC, AB and YK. Age-6 growth was assessed in 2008. Data from the trial is being used to develop deployment guidelines for Class A and B spruce seed in the climate based seed transfer system. The trial will be re-assessed in 2014 and data used to refine seedlot selection of spruce in BC.

Publications

D.H. Ikeda, H.M. Bothwell, M.K. Lau, G.A. O'Neill, K.C. Grady and T.G. Whitham. A genetics-based Universal Community Transfer Function for predicting the impacts of climate change on future communities. Functional Ecology. http://onlinelibrary.wiley.com/doi/10.1111/1365-2435.12151/abstract

J.M. Kranabetter, M.D. Stoehr and G.A. O'Neill. 2012. Divergence in ectomycorrhizal communities with foreign Douglas-fir populations and implications for assisted migration. Ecological Applications 22:550-560. http://dx.doi.org/10.1890/11-1514.1 http://www.esajournals.org/doi/abs/10.1890/11-1514.1?journalCode=ecap

R. Oney, B. Reineking, G. O'Neill, and J. Kreyling. 2013. Intraspecific variation buffers projected climate change impacts on Pinus contorta. Ecology and Evolution 3:437-449. http://dx.doi.org/10.1002/ece3.426

John H. Pedlar, Daniel W. McKenney, Isabelle Aubin, Tannis Beardmore, Jean Beaulieu, Louis Iverson, Gregory A. O'Neill, Richard S. Winder and Catherine Ste-Marie. 2012. Placing Forestry in the Assisted Migration Debate. Bioscience 62: 835-842. http://dx.doi.org/10.1525/bio.2012.62.9.10

T. Wang, E.M. Campbell, G. A. O'Neill and S.N. Aitken. 2012. Projecting future distributions of ecosystem climate niches: Uncertainties and management applications. For. Ecol. Manage. 279: 128-140. http://dx.doi.org/10.1016/j.foreco.2012.05.034

5.0 Decision Support Advisory Commitee

Susan Zedel

During the 2012-13 year, the Decision Support Advisory Committee (DSAC) continued with projects initiated during the first year of the committee (2011-12) and proposed some new projects.

The DSAC is responsible for identifying the needs for clients, exploring decision support options, developing proposals and submitting the proposals and budget to the FGC for approval and support. The committee works closely with Tree Improvement Branch on project management and development of decision support tools.

The main project sponsored by DSAC in 2011-12 was the creation of seedlot 'area of use' spatial geometry. The completion target date of March 2013 was not met due to technical systems issues within government. The completion date for the project was moved to the next fiscal year, with the contractor Vivid Solutions Inc. continuing the work. When the project is complete clients will be able to view the spatial seedlot 'area of use' polygons using SeedMap, Mapview, ArcGIS and new decision support tools yet to be developed. Queries and reports on deployment of seedlots in specific openings and across the landscape using spatial data will be developed using this new data.

Funding was allocated by DSAC in 2012-13 for the scientific analysis required to develop climate based seed transfer (CBST). The CBST project was not at a stage to require decision support tool development by the end of the 2012-13 year, so this project was moved to the next fiscal year.

DSAC members contributed ideas to Seed Planning and Registry system (SPAR) maintenance and enhancements, with the budget for SPAR work coming from Corporate Services for the Natural Resource Sector (CSNRS). A new SPAR Seedlot Usage report was developed and implemented to assist seedlot owners in tracking the use of their seedlots.

Membership of DSAC was changing at the end of the 2012-13 year and the committee was looking for new representation from industry and government.

6.0 Operational Tree Improvement Program

Lee Charleson

The objective of the Operational Tree Improvement Program (OTIP) is to increase the quality and quantity of select seed produced from existing industry and Ministry of Forests, Lands and Natural Resource Operations seed orchards.

To meet this objective, a Call for Proposal process is administered each year in support of FGC objectives and based on priorities developed by the Interior and Coastal Technical Advisory Committees. FGC committees review and rank these proposals based on technical merit, impact, value and costs.

As a result of this work, the Land Based Investment Strategy Tree Improvement Program is supported through key investments in:

- Boosting genetic gain in seed orchards through grafting, ramet removal and replacement, and pollen management
- Boosting seed production through induction, pest management and supplemental pollination, and
- Supporting technical projects that address issues preventing orchards from meeting production objectives.

OTIP uses a performance measurement system to monitor progress and set reasonable targets for project success. This year, as in past years, orchardists and researchers have responded to this approach and have achieved and exceeded planned targets.

For additional information regarding the budget and key performance indicators, please refer to the FGC Annual Report 2012/2013 at http://www.fgcouncil.bc.ca/FGC-AnnualReport-1213-04Nov2013-web.pdf

An OTIP Eligibility Review Committee was struck in 2012. The committee identified current OTIP issues causing concern and met to discuss the items. Proposed changes were brought forward to FGC resulting in new guidelines for OTIP projects eligible for funding. Collaborative work by FGC and the ministry was done to overhaul and improve the call for proposals document including the development of an excel spreadsheet for OTIP project budget submission.

6.1 Orchard Projects

6.1.1 Saanich Forestry Centre (WFP)

Annette van Niejenhuis

Western Forest Products (WFP) manages tree seed orchards for forest regeneration programs in the Maritime zone at the Saanich Forestry Centre on the Saanich Peninsula. Our orchards include low and high elevation Douglas-fir, low elevation western redcedar, low and high elevation western hemlock, and low elevation Sitka spruce seed orchards as well as yellow cypress hedge orchards. As a collaborator in the Forest Genetics Council programs, WFP receives OTIP funds to implement incremental orchard management techniques to deliver quality seed in quantity to the coastal forest regeneration programs.

Low Elevation Coastal Douglas-fir Crop and Orchard Enhancement

Revised scores for a number of established orchard parents were received, resulting in revisions to orchard plans. Replacement grafts (117) were purchased. Ten ramets were replaced in orchard 405 in the third quarter. In the fourth quarter, planning and site preparation was undertaken for ramet replacement in the first month of the following year. Nutrient management continued with fertilization of replacement stock for good crown development. Significant fencing work to maintain a deer-free orchard is now complete at WFP's expense.

Phenological and reproductive bud surveys together with pollen monitoring were used to determine the male parental contribution to the seed crop. Supplemental mass pollination was implemented for early and late clones.

Contarinia spp. counts exceeded the threshold; thus, a control treatment was applied in early May. The 2012 cone crop yielded 39.4 hl of cones for 11.3 kg of seed with an estimated 25% pollen contamination resulting in a Genetic Worth of 9.

High Elevation Douglas-fir Orchard Enhancement

Forty-five grafts were purchased early in the year. Revised scores for a number of parents were subsequently received, resulting in changes to the orchard plan and requirements for further grafting. Nineteen ramets were planted in the orchard. Nutrient management for the promotion of good crown development continued. Significant fencing work to maintain a deer-free orchard is now complete at WFP's expense.

Western Redcedar Crop and Orchard Enhancement

Seventy-five grafts were purchased to continue the upgrading of the redcedar orchard. Forty-two large ramets from the holding bed were planted, increasing the orchard breeding value from 17.9 to 18.6. Nutrient management of the replacement stock continued.

The 2011 cone crop showed poor seed set with high seed insect infestations. The crop was not harvested. The reproductive bud surveys for the 2012 crop indicated an average crop. Supplemental mass pollination was implemented between February 23 and March 1.

Conelette dissections showed light midge infestation thus pesticide application was not required.

High Elevation Western Hemlock Orchard Enhancement

As seed demand for high elevation western hemlock has decreased in the past years, many years' seed supply of good genetic quality is currently banked. OTIP funds were approved only to maintain the replacement orchard for future high gain crops, this included moving tags and applying fertilizer. However, at our expense WFP planted 8 replacement ramets in orchard 187. Additionally, we implemented a supplemental mass pollination program in the tiny crop. Seed for potentially 29 k plantables and a genetic worth of 11 was harvested.

Similarly, significant amounts of low elevation western hemlock seed of good genetic quality is banked. Until work is undertaken to raise the average breeding value of the parents in the WFP orchard by roguing and replacing ramets, no OTIP activities are taking place.

Sitka Spruce Orchard Enhancement

A large supply of good genetic quality seed is banked from the 2010 crops of the Maritime zone Sitka spruce orchards. Only orchard maintenance and foliar pest management activities were approved for OTIP funding. Orchard replacement stock was fertilized. Green aphid surveys indicated population levels below treatment thresholds, and no other foliar insects showed significant presence; no treatments were required.

Yellow Cypress Production Hedges Enhancement

Hedge maintenance of the high gain orchard continued with fertilization treatments and a pesticide treatment for trisetacus mites. Sixty-seven donor plants were added to the orchard to fill vacancies. Light top pruning of donors to maximize cuttings production was undertaken. Cuttings material for an estimated 210 k plantables with genetic worth of 20 was produced. Propagation for a replacement hedge was initiated as a rooting trial to confirm that the selected good rooters continue to perform.

6.1.2 Mt. Newton Seed Orchard (TimberWest (TW) Forest Company)

Tim Crowder

Douglas-fir

SPU0106 covers activities in five Fdc M Low orchards: 134, 154, 183, 197 and 404. The management objective is to increase the genetic worth of these orchards from the current 12% to approximately18% by 2015, and maintain an average annual production of 5 million trees.

These orchards contain a total of 5,213 ramets, about half of which are not yet in production. 500 more trees were grafted this year, and an additional 250 trees were purchased from CLRS. 450 trees were established in the fall. 625 trees which were too small to plant out were maintained in holding beds.

SMP was required to augment the insufficient pollen cloud on 380 trees of the early and late clones. Both fresh and stored, high breeding value pollen was used and all stored pollen was tested before use. 4 litres of pollen was collected, dried and stored for future use. Internal and external pollen flights were monitored and a contamination rate for foreign pollen was calculated.

Insect pests were monitored and due to low numbers of damaging insects, a spray program was not carried out this year.

$GA_{4/7}$ injections and double overlapping girdles were used to induce a 2013 crop on 892 ramets.

77 large ramets with GW<7 were rogued from the orchards during the winter and the stumps removed to create new planting positions, and a further 294 young trees were removed due to a recent change in the breeding values.

A total of 160 hectolitres Fdc cones were collected, that yielded enough seed for approximately 2.75 million trees.

Plate 19. Shipping Douglas-fir cones to the BC Tree Seed Centre.

Western red cedar

SPU0205 covers activities in two Cw M Low orchards: 140 and 152. These two orchards are similar in composition and are typically induced in alternating years to provide a steady seed supply. The management objective for these orchards is to produce enough seed for 2 million seedlings with a gain value above 18%.

226 orchard trees were maintained and managed. The orchards were monitored for insect pests, however infestation levels did were low so there was no need to apply insecticide.

52 trees were sprayed with GA_3 in July to induce a crop for 2013.

325 grafts from series 3 to 6 were maintained in holding beds awaiting field test results.

2.4 hectolitres of cones were collected that yielded enough seed to produce 0.3 million seedlings with a genetic gain of 20%.

Plate 20. 3rd generation Douglas-fir graft.

Plate 21. View from the TimberWest seed orchard office.

Plate 22. Orchard # 404 – 3rd generation Douglas-fir.

Plate 23. Orchard # 404 – 3rd generation Douglas-fir.

Plate 24. Orchard # 404 – 3rd generation Douglas-fir.

Plate 25. Harvesting mature Fdc with a 60 foot lift.

Plate 26. Harvesting the first crop on the 3rd generation orchard with a 12 foot ladder.

6.1.3 Saanich Seed Orchards

Lisa Meyer

Genetic Enhancement and Production of Seed Crops from Douglas-fir Seed Orchard #199 (SPU 0114)

The management objective of this project was to improve the genetic quality and the quantity of seed crops produced from the Douglas-fir Seed Orchard #199 at the MFLNRO Saanich Seed Orchard site. This moving front orchard design allows for early seed production with the interim orchard that gradually giving way to the final orchard once all the genetic gain selections are complete. The specific activities are identified in Table 4.

Orchard Management Operations to Maintain Productivity and Increase Gain in Seed Orchard #181 SM Fdc (SPU 1902)

The objectives of this project are to enhance the seed yield and genetic worth and quality of seedlots produced in Orchard #181 by roguing according to progeny test results, utilizing orchard management techniques to optimize growing stock vigour and crop health, and monitor for and apply pest control if necessary. See Table 4 for specific SPU activities.

Orchard Management and Seed Crop Production in Seed Orchard #175 Rust Resistant White Pine (SPU 804)

Saanich Seed Orchard is working with the Pw Breeding program to develop a rust resistant white pine orchard. Supplemental mass pollination (SMP) techniques are being used to apply Major Gene Resistant (MGR) pollen to the Slow Canker Growth (SCG) and Difficult to Infect (DI) white pine ramets. The deliverable from this project is a vigorous orchard that is capable of producing SCG and DI seedlots of rust resistant seedlings. See Table 4 for specific activities.

PROJECT	SPECIES	ORCHARD #	RAMETS IN ORCHARD	RAMETS IN HOLDING
SPU 0114	Fdc	199	1576	346
SPU 1902	Fdc	181	882	254
SPU 0804	Pw (R)	175	551	80

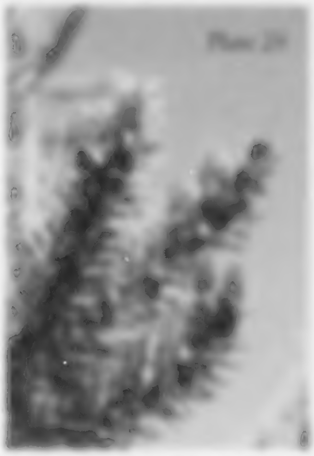
Table 3. Saanich Seed Orchards.

PROJECT	GRAFTS PURCHASED	POLLEN COLLECTED (litres)	SMP APPLICATION	RAMETS ROGUED	RAMET REPLACEMENT	PEST MANAGEMENT	ORCHARD MANAGEMENT
SPU 0114	250	2.2	824	150	150	1922	1576
SPU 1902	-	6.5	65%	-	-	1136	882
SPU 804	0	-	-	-	80	551	-

Table 4. Saanich Seed Orchards OTIP Funded Project Activities.

Plates 27 & 28: Saanich Seed Orchard Douglas-fir Seed Orchard #166. (Photos: Chris Hallstrom)

Plates 29 & 30: Saanich Seed Orchard Seed Orchard 168 Douglas-fir #181. (Photos: Chris Hallstrom)



Plates 31 & 32: Saanich Seed Orchard Rust Resistant Western White Pine Seed Orchard #175. (Photos: Chris Hallstrom)

6.1.4 Kalamalka Seed Orchards

Gary Giampa

In 2012/2013, Kalamalka Seed Orchards received FGTP approval for 7 projects under the operational production sub-program, including 3722 on page 42. The funding allowed for a significant enhancement of the effectiveness of our orchards in delivering improved seed. Activities included:

- Improving orchard composition through grafting higher breeding value scions, maintaining recently grafted high value scions destined for orchards, and transplanting the older higher value ramets in the orchards;
- Improving orchard seed quantity and quality through cone induction and pollen management, including collecting high breeding value pollen from clone banks and applying Supplemental Mass Pollination; and
- Improving orchard productivity through pest management and other management activities.

Project	Species	SPZ	Orchard	Grafts Made	Maintained	Rogued	Transplants	Induction
SPU0701	Pli	NE	347		102	375	32	
SPU1501	Pw	KQ	335		23		29	
SPU1708	Pli	BV	230	100			147	
SPU2201	Fdi	NE	324					502
SPU3501	Sx	BV	620					
SPU3801	Fdi	EK	336					175
Totals				100	125	375	208	677

Table 3: Orchard Quality and Quantity Boosting Activities by Project

Project	Species	SPZ	Orchard	Pollen Collected (Vols. ml)	Trees Pollinated
SPU0701	Pli	NE	307/347	3.0	1,867
SPU1501	Pw	KQ	335	0.0	1,060
SPU1708	Pli	BV	230	2.0	800
SPU2201	Fdi	NE	324	2.5	1,557
SPU3501	Pli	EK	340	3.0	1,819
SPU3801	Fdi	EK	336	1.7	
Totals				13.2	7,141

Table 4: Pollen Management Activities by Project

Pest management activities included:

- monitoring pest levels to make informed decisions regarding control;
- using Safer's Soap sprays to control adelgids in Sx and Fdi;
- removing weevil-infested spruce leaders to reduce weevil populations;
- removing pine pitch moths damaging orchard tree stems;
- baiting for control of rodents feeding on tree roots;
- sanitation picking of cones in orchards with non-collectible crops to reduce pest populations;
- spraying to control Dioryctria in Pw;
- spraying to control mites in Fdi;
- applying dormant oil to control both adelgids; and
- spraying to control Leptoglossus in Pw and Pli.

The FGTP funding was instrumental in increasing both the quantity and quality of seed produced. At Kalamalka in 2012 we produced approximately 309 kg of western larch, lodgepole pine, and western white pine seed equivalent to over 66 million seedlings with an average GW of +15. Large areas of the interior of the province are using Kalamalka seed.

8.1.3 Vernon Seed Orchard Company (VSOC)

[illegible]

Operational Tree Improvement Program (OTIP) has once again provided funding for seed orchard production companies to successfully produce improved seed for industry and the province of BC.

[illegible]

Vernon Seed Orchard and BC Tree Improvement have benefited again with the financial support provided through OTIP.

[illegible]

[illegible]

Monitoring of pests was carried out monthly in particular European pine shoot moth.

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Monitoring of pests was carried out monthly in particular European pine shoot moth.

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Monitoring of pests was carried out monthly in particular European pine shoot moth.

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Monitoring of pests was carried out monthly in particular European pine shoot moth.

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Monitoring of pests was carried out monthly in particular European pine shoot moth.

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6.1.7 Eagle Rock Seed Orchards (Tolko Industries)

Tia Wagner

Four orchards are managed by Tolko Industries for the Thompson Okanagan seed planning zone. Three orchards, two interior spruce and one lodgepole pine, are SelectSeed Co. Ltd. partnership orchards. Projects funded by the Operational Tree Improvement Program aid in improving the quality and quantity of seed produced for the Thompson Okanagan forest community. In 2012, Eagle Rock produced seed for 13.4 million lodgepole pine and 17.3 million white spruce seedlings for reforestation in the Thompson Okanagan seed planning zone.

SPU 14 Thompson Okanagan Pli High, Orchards 230 (Tolko) and 339 (SelectSeed), Project 1001

- When pollen and flower surveys indicated optimal receptivity, supplemental mass pollination was completed with the aid of an air blast sprayer.
- Pocket gophers were controlled by administering bait in the spring.
- Pest monitoring was completed for *Eucosma*, *Dioryctria auranticella*, *Rhyacionia buoliana* and *Leptoglossus occidentalis*. Although all pest populations had increased from 2011, no control was required.
- *Synanthedon sequoiae* and *Dioryctria* spp. were manually removed from the base of young ramets to prevent girdling and full or partial ramet loss.
- Leaders were pruned off in June to control height and increase crown branching and tree form.
- Scion was collected (500) from high breeding value and performing clones from orchard 230 for the orchard 339 replacement. Grafting was completed at Skimikin Nursery and ramets will be held until planting in 2014.
- Phenology and cone collection was completed for OTIP#722. Information and samples were sent to Kalamalka Seed Orchard for processing.

SPU 29 and 30 Thompson Okanagan Sx Low, Orchard 342 and Sx High, Orchard 343 (SelectSeed), Orchard 303 (Tolko) Project 2803

- Two litres of pollen was applied, using pollen misters, to early and late flowers in both young spruce orchards (342, 343). During peak flower receptivity and pollen readiness, an air blast sprayer was utilized for optimum pollination.
- Monitoring for pests such as *Adelgids*, *Pissodes strobi*, *Oligonychus ununguis*, *Dioryctria abietivorella* and *Choristoneura occidentalis* was completed.
  - Leaders containing *Pissodes strobi* were removed in June to decrease the population within the orchard.
  - To increase health in small ramets, *Oligonychus ununguis* was controlled in March in both orchards.
  - No control was required for *Choristoneura occidentalis* and *Dioryctria abietivorella* as both experienced up to 50% parasitism.
- Pocket gophers were controlled by administering bait in the spring.
- Orchard 303 was retired in 2012. As a result, 500 trees were removed, chipped and transported to the COGEN plant.

Plate 38. TC(LRC) lodgepole pine pollen cluster releasing pollen grains.

Plate 39. TC(LRC) Corey Stuart moving pollen within a lodgepole pine orchard with an airblast sprayer.

6.1.8 Prince George Tree Improvement Station (PGTIS)

Rita Wagner

SPU 1203, 1802, 1702

Activities are aimed at increasing the quantity and quality of lodgepole pine seed from Orchard 220 (Prince George low seed planning zone), Orchard 223 (Central Plateau low seed planning zone) and Orchard 228 (Bulkley Valley low seed planning zone).

Three Operational Tree Improvement Projects were conducted at the Prince George Tree Improvement Station in 2012-2013.

Phenology surveys were completed to keep track of receptivity periods which can vary considerably from year to year.

Pollen flights were monitored. Outside pine pollen flight is basically non-existent due to the devastation caused by the mountain pine beetle.

October foliar samples were taken for nutrient analyses. Fertilizer applications were increased ensuring maximum ramet health.

Branch damage caused by hydraulic lifts, heavy & wet snow loads and strong winds required tree maintenance.

Surveys for western gall rust, *Elytroderma* needle cast, *Lophodermella* pine needle cast, *Zelleria* pine needle-sheath miner, *Cecidomyia* pinch midge, and various other insects were completed. Some topping as well as extensive bottom-branch and access pruning was completed in all three orchards.

Lindgren traps were set up throughout the site to monitor secondary bark beetle flights (mainly Ips). Since 2009, mountain pine beetle activity in the Prince George area continues to drop.

Since 2005 all three orchards had three years of very high production, two years of medium high production and two years of medium-low production. However, even the medium-low production still exceeded the FCG target forecast for each orchard. In 2012, the three provenance orchards yielded 27.66 kg of seed, the equivalent of approx. 5.6 million potential seedlings with a genetic worth of 6%.

Due to an early cold spell and heavy snowfall in late October collection of the serotinous clones in orchard # 223 had to be abandoned. The remaining crop (approx. 10 hl = 5 kg seed = 1 mill. seedlings) will be collected in summer 2013.

Some squirrel trapping was required to avoid seed loss and loss of potential cone sites.

6.1.9 Skimikin Seed Orchards

Hilary Graham

Summary for Projects 0404, 0411, 1008, 1211, 1504, 2001, 3502, 4002, and 4057E13.

Skimikin seed orchards are comprised of 13 orchards covering 9 SPUs and 4 conifer species – interior spruce (Sx), western white pine (Pw), lodgepole pine (Pli), and Ponderosa pine (Py). There are also research plantations covering a wide variety of species and projects. Seven Sx orchards produce seed for the Bulkley Valley, Peace River, and Nelson seed planning units. One Pw orchard produces rust resistant seed for the Kootenay Quesnel SPU and a 2nd Pw orchard for the same SPU is nearing production. The three young Pli orchards will produce seed for the Thompson Okanagan low, Nelson high, and Prince George low SPUs.

In 2012/13, 9 projects received OTIP funding for activities to increase the yield and genetic gain of seed produced in the Sx, Pli, and Pw orchards. These activities included holding grafts, planting grafts, cone induction, roguing, insect and disease monitoring and control, and rodent control. In addition, one project provided funding for research plantation maintenance and development, and another project covered activities to monitor and control the Mountain pine beetle.

Interior spruce – orchards 301 (0404), 207/208/229 (3502), and 212/213 (4002)

For the Bulkley Valley low orchards 207, 208, and 229, spruce budworm was controlled by a *Bacillus thuringiensis* spray in June. To increase genetic gain, low breeding value ramets were rogued from orchard 208 and 229. A total of 156 ramets in orchard 208, and 148 ramets in orchard 229 were removed.

In the Sx West Kootenay low elevation orchard 301, 400 ramets with low breeding values were removed.

In the spruce orchards for the Peace River low and mid elevation zones (orchards 212 & 213) 80 grafts were made in the spring and maintained in a holding area for planting in 2013. An additional 103 grafts were maintained in a holding bed. Five hundred ramets were induced for cone production with Gibberellic acid (GA), and 1/3rd of the ramets in each orchard were topped to a height of 4 metres to manage the crowns to a reasonable height.

All Sx orchards at Skimikin were monitored throughout the season for damage caused by insects, disease, and rodents. Rodents were controlled by poison baits. In 2012 there was no crop produced in the Sx orchards so any funding for cone and seed pest control was returned.

Lodgepole pine – orchards 349 Nelson high (2001), 350 Thompson Okanagan low (1008), and 352 Prince George low Western gall rust resistant (1211)

The young Pli orchards at Skimikin were all monitored for pest damage from April to September. Pitch moths were removed by hand in the spring and fall, and leaders attacked by the European pine shoot moth were cut off and disposed. Rodents were controlled by poison baits.

Western white pine – orchard 351 Kamloops-Quesnel (1504)

This young Pw orchard was monitored for pest damage from April to September. Pitch moths were removed by hand in the spring and fall. Rodents were controlled by poison baits.

Research Plantations (0411)

The on-site research plantations and trials were monitored for insects, disease and rodent damage. All plantations and trials were mowed, treated with herbicide, and hand weeded where necessary. Rodents were controlled in all areas by poison baits. The *Ribes* garden was maintained through watering, mowing, and hand weeding. In June, the two young Sx plantations were sprayed with *Bacillus thuringiensis* (BT) for spruce budworm control. The new Sx plantation was also sprayed with BT for budworm control, and the bands between the rows were grass seeded in the fall. The Pli breed arboretum was irrigated, weeds controlled, inter-row areas grass seeded, pitch moths were removed by hand, and the trees were topped to manage the crowns. Also, 700 grafts were planted into the Pli breed arboretum, and 1400 grafts were planted into a holding bed for a 2nd Pli breed arboretum.

Mountain Pine Beetle (4057E13)

Pheromone traps were set up in the spring and checked once a week from May through September. The trap counts peaked the third week in July but numbers were very low.

No orchard trees were attacked by the Mountain pine beetle in 2012.

Plate 40. Margaret Lazar removing pitch moth larvae in orchard Pli 352.

Plate 41. Skimikin staff 2012.

Plate 42. Alle Palmer plants grafts in holding area for the Pli breeding arboretum.

Plate 43. Steven Farrell rogues low breeding value ramets in Sx 207.

6.1.10 Kettle River Seed Orchard Company (KRSO)

Rick Hansinger

Pollination and Pest Management in Central Plateau (CP) Orchard 23 – Lodgepole Pine (SPU 12)

Objectives

Collect and store 3.0 litres of pollen for SMP in young Pli Orchard 237 to increase the production of Class A seed to 1,500 ('000s) potential trees for sowing year 2013.

Minimize filled seed losses from predation by *Leptoglossus* through pesticide applications.

Results

9.0 l of pollen was vacuum collected in the Pli PG low orchard which was cleaned, dried and stored for application spring 2013 Genetic Worth G+16.7 Class A. Approximately 6 litres of pollen was applied to 3,500 ramets during the receptivity period from May 20 to June 10. The Pli PG orchard is now producing sufficient pollen to meet SMP and open pollination requirements. Three SMP passes were completed in order to ensure early and late receptive clones received sufficient pollen to fertilize female conelets. Remaining late pollen was air blasted with a turbo fan sprayer. 6 litres of pollen was stored for SMP spring 2013.

Developing cones were inspected for the presence of *Leptoglossus* and the risk to the seed crop was deemed negligible, pesticides were not applied.

Output and Deliverables

69.6 hl of cones were collected. The final seed crop was 19,301 g of seed @ 236 seeds/g. The seedlot tested at 97% germination and 2.01 seeds per seedling.

Pollination and Pest Management in Central Plateau Orchard 238 – Lodgepole Pine

Objectives

Collect and store 3.0 litres of pollen for SMP in young Pli Orchard 238 to increase the production of Class A seed to 1,000 ('000s) potential trees for sowing year 2013.

Minimize filled seed losses from predation by *Leptoglossus* through pesticide applications.

Results

3.0 l of pollen was vacuum collected in the Pli PG low orchard which was cleaned, dried and stored for application spring 2013. Genetic Worth G+21 Class A. Approximately 4.5 litres of pollen was applied to 3,000 ramets during the receptivity period from May 20 to June 10. The Central Plateau Pli orchard is now producing sufficient pollen to meet SMP & open pollination needs. Three SMP applications were completed in order to ensure early and late receptive clones received sufficient pollen to fertilize female conelets. Remaining late pollen was air blasted with the turbo fan sprayer. 6 litres of pollen remains in storage for spring 2013 SMP.

Developing cones were inspected for the presence of *Leptoglossus* and the risk to the seed crop was deemed negligible, pesticides were not applied.

Output and Deliverables

55 hl of cones were collected. The final seed crop was 14,820 g of seed @227 seeds/g. The seedlot tested at 95% germination and 2.01 seeds per seedling.

Plate 44. Installation of insect bags for OTIP temporal cone collection 0722 study.

Plate 45. Fertilization spring 2013.

Plate 46. Roger Painter assisting with female gamete contribution surveys.

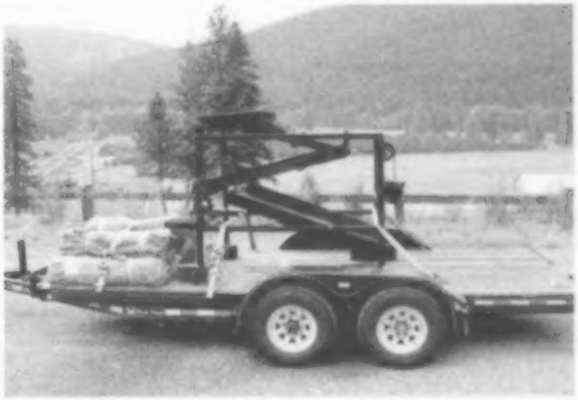

Plate 47. Custom cone cleaner fabricated using operational designs already in existence plus modifications to improve function.

Plate 48. SMP from elevated platform.

Plate 49. Cone bay storage. 100 sacks per bay.

6.1.11 Sorrento Seed Orchards

Dave Barnard and Tia Wagner

Sorrento Seed Orchard manages two large lodgepole pine orchards established in 2003 in partnership with SelectSeed Company. These orchards supply seed for the Central Plateau (CP) low elevation and the Bulkley Valley (BV) low elevation seed planning units.

SPU 17 Bulkley Valley Pli low, Orchard 240 OTIP 1707 & SPU 18 Central Plateau Pli Low, Orchard 241 OTIP 1803

Supplemental Mass Pollination (SMP)

Although both orchards are beginning to reach maturity, they currently do not produce a sufficient amount of pollen to adequately fertilize receptive flowers and yield an acceptable amount of seeds per cone. Therefore, when phenology surveys indicated optimal female receptivity, SMP was completed manually using pollen misters. In addition, an air blast sprayer was utilized during peak pollination to increase the pollen cloud. Three applications of manual SMP and two passes with the sprayer were completed in 2012.

Using a backpack vacuum, 3 litres of pollen for Bulkley Valley 240 and 2 litres for the Central Plateau 241 were collected, processed and stored at Sorrento Nurseries.

Pest Management

Protecting cone crops and ramets from pest damage is fundamental to ensuring minimal loss to ramet health and seed yield. Table 7 below details monitoring and control outcomes.

Crown Management

Crown/leader pruning was completed in June to both control ramet height and increase health, vigour and crown formation. A shearing knife was used to remove dominant leaders, which encourages lateral growth and increases future cone bearing sites. Approximately one third of each orchard was pruned in 2012.

OTIP 0722 – Crop Statistics

Data and cone collection was completed in orchard 240 (BV) for OTIP0722. Samples and information were sent to Kalamalka Seed Orchard for processing.

Funding provided through OTIP aids in achieving the Forest Genetics Councils goal for producing a high quantity and quality of seedlings for Central Plateau and Bulkley Valley seed users.

Pest Surveyed	Results	Control
Leptoglossus occidentalis	No more than 3 insects per 30 min survey	No control required
Dioryctria aurenticella	Less than 5% damage on cones	No control required
Rhyacionia buoliana	14% of 100 shoots surveyed reveal damage	No control completed, pheromone monitoring in 2013
Eucosma spp.	7% of 100 shoots surveyed reveal damage	No control required. Pheromone trap to confirm identity in 2013
Synanthedon sequoia	Increase in damage. Mortality -4 ramets	Manually removed from each ramet in both orchards
Voles	Increase in vole activity, young ramets suffered mortality from root feeding	Bait control required in 2013

Table 7. Pest Management Monitoring and Control Outcomes at Sorrento Seed Orchards.

6.2 Technical Support Programs

6.2.1 Increasing Quality, Genetic Gain, and Quantity of Yellow Cypress Cuttings (SPU 1113)

Mark Griffin, John Ogg, Craig Ferguson and John Russell

Introduction

This project involves increasing the quantity and quality of high-value yellow cedar cuttings for the coastal program.

Objectives include:

1. provide the cultural treatments required to improve hedge production, and
2. enhance hedge composition by replacing lower-genetic-value families and clones with newly tested, improved clones.

Plate 10. Potted replacement and new ramets prior to initial pruning.

2012/2013 Highlights

Pruning of hedges occurred in April 2012. This year the pots were topdressed with Nutricote 18-6-8 type 180, augmented with applications of bi-sol. For pest control, predaceous nematodes were applied regularly to control root weevils.

During 2012, a large amount of rogueing was done and the number of contributing ramets in the hedge has been reduced to 66 clones with 6,280 ramets. The rogueing was based on the results of rootability studies where samplings of every clone were previously set and each clone's propensity to root was assessed. Poor rooting clones have therefore been culled from the operational hedge.

With the removal of the poorly rooting clones, it is now estimated that the hedge is made up of stock where at least 60% of the cuttings supplied to the nurseries will yield a plantable "seedling" at the end of 10 months of growth in the greenhouse. We expect the 6,280 ramets currently in the hedge will be able to supply some 155,000 cuttings.

To replace the rogued material and to reinvigorate the hedge, material from series 3 selections have been set and additional clones are being added based on field data. These additions are currently of a size where they are to be transferred to stoolblock 815Ks.

In late 2012, some 134,000 cuttings from this operational hedge were supplied for production to reforestation nurseries.

Plate 11. Mature donor stock ready for harvest.

6.2.2 Estimating 2012 Pollen Contamination for Coastal Douglas-fir Seed Orchards

Joe Webber

OTIP0113

The 2012 contamination levels in the Western Forest Products (WFP 166) and TimberWest (TW 143) orchards were 31.7% and 29.0% respectively. These values were calculated using the mean pollen load (PL) from three regional monitors and two orchard monitors (%Contamination = (Regional PL/Orchard PL)*100). Contamination values at WFP have been estimated for the past eight years (2005–2012) and five years (2008–2012) at TW (Table 8). Over this period, regional pollen loads have ranged from a low of 5 (2005) to 40 (2009). Over the same period, orchard pollen loads (WFP) have varied from a low of 28 (2010) to a high of 115 (2007). In general, orchard and regional pollen loads trends follow each other (Figure 9) suggesting that pollen production in both orchard and non-orchard trees is the result of the same environmental induction conditions.

For the last three years, regional pollen loads have been relatively low (7-15) but orchard pollen loads have

Douglas-fir Orchard Pollen Monitoring: 7-day Mean Pollen Load (grains/cm²/day) and %Contamination

	WFP								TW				
	2005	2006	2007	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
REG-PL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ORCH-PL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
%Cont													
PM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					

Table 8. Regional (REG) and orchard (ORCH) pollen load (PL) values (2005–2012) and estimates of contamination for two Douglas-fir orchard sites using pollen monitoring (PM) and DNA paternity analyses.

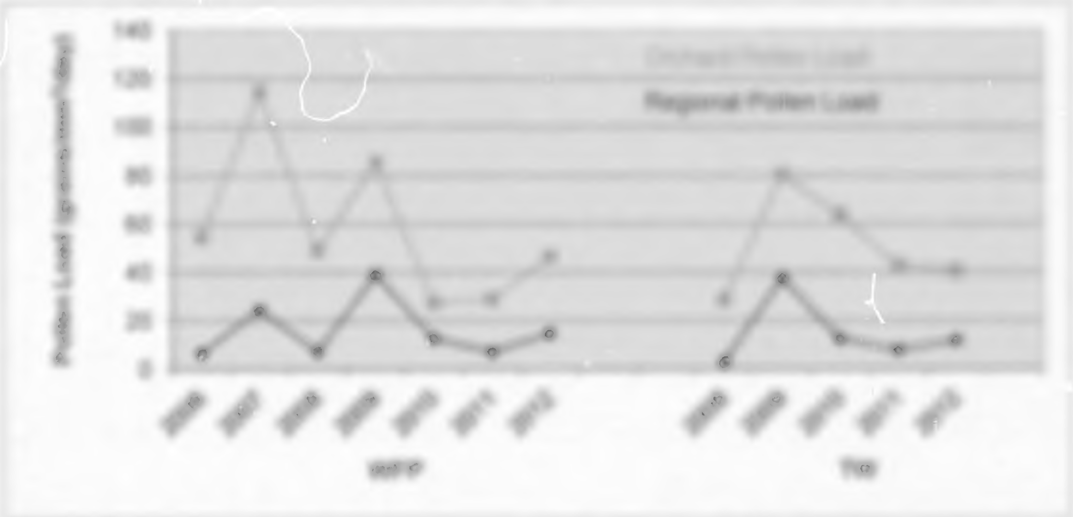

Figure 9. Variation in orchard pollen loads at the WFP 166 and TW 143 Douglas-fir orchards and regional pollen loads for 2005–2012 (WFP) and 2008–2012 (TW).

due from low loading to generally high contamination levels ([illegible]% for WFP and [illegible]% for TW). In 2010 and 2011, contamination levels at TW were lower than WFP which was largely attributed to higher orchard pollen loads arising from substantially more mature, pollen producing trees (about [illegible] at TW and [illegible] at WFP).

The spring receptivity period for the last three years (2010–2012) was cool and wet. Since orchard phenology progressed slowly, the Orchard Adjustment Factor (OAF) could be calculated. The OAF was derived from the mean sum of daily ratios of early orchard pollen load to early regional (contamination) pollen load. Only dates prior to orchard shed were used.

For all three years, adjusting the regional pollen data with the OAF using only early pollen capture data decreased the regional pollen load by an average factor of [illegible] and [illegible] for WFP and TW respectively (Table 9). The three year mean for contamination without the OAF was [illegible]% and [illegible]% for WFP and TW respectively. Applying the OAF factor to adjust the regional pollen load decreased the three year mean contamination values to [illegible]% and [illegible]% for WFP and TW respectively.

The orchard adjustment factor is very sensitive to a low pollen sensor capture by either the orchard or regional monitors. While the OAF has reduced regional pollen load values for the last three years, it has not consistently reduced contamination in all past years. Since calculation of the OAF varies by these seed/orchard systems, its use must be carefully monitored. While the simple ratio of regional to orchard pollen loads is recommended, it is also noted that the error of pollen monitoring techniques will increase with increasing pollen loads. The extent of this error will be determined by the more robust DNA technique (El Kassaby [illegible]) currently being applied to those seed crops where high contamination values have been estimated.

	[illegible]			OAF		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WFP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TW	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	[illegible]			[illegible]			[illegible]		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WFP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TW	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 9. Contamination values for [illegible] calculated using pollen load (%) values adjusted with the Orchard Adjustment Factor (OAF).

6.2.1 Collection of Crop Statistics for Interior Lodgepole Pine Orchards

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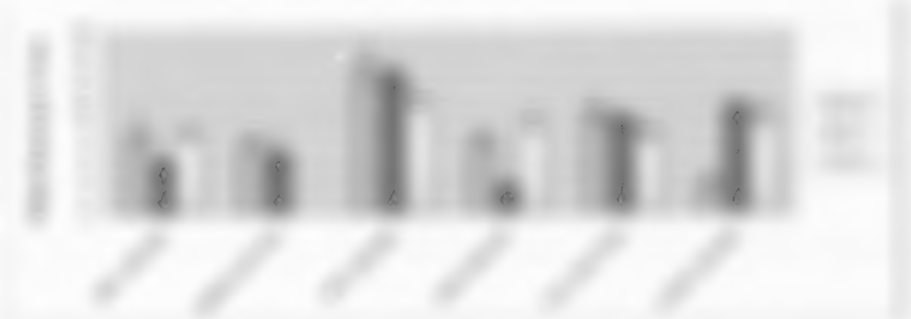
[illegible]

[illegible]

[illegible]



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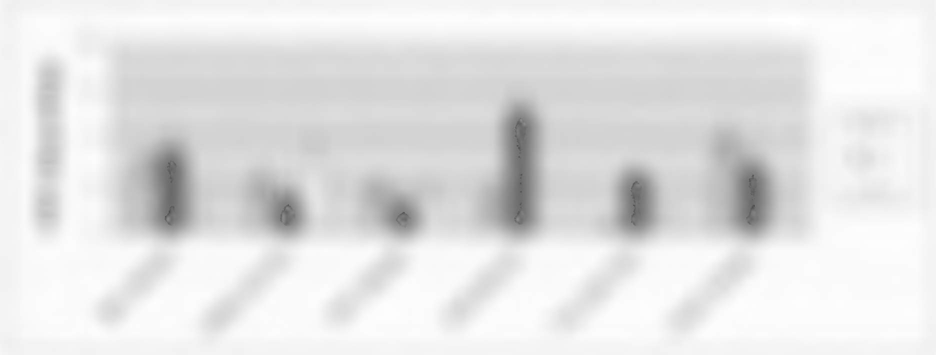

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

6.2.4 Cone Induction in Lodgepole Pine Seed Orchards OTIP Project SPU 1213

Roger Painter

Cone induction has been successfully used as a method of increasing seed yield in BC with many species. Up to now tests with cone induction in lodgepole pine have shown some effectiveness with specific clones but not as an overall technique. Tests done since 1980 using various techniques were applied based on the assumption that May-June was the time frame when differentiation occurred. More recently Dr. Lisheng Kong and Dr. Patrick von Aderkas studied the phenological development of lodgepole pine and discovered that differentiation occurs later in the year at or near July through August. Previous results, showing that the effects of treatment were hit and miss and in some instances clonal specific and may have been related to those clones being early developers phenologically.

Testing techniques for cone induction are very easy to initiate and are relatively inexpensive. The project focussed on using GA 4/7 with known rates of application based on past trials with pine and other species and encompassing the newly understood time frame for differentiation based on work done by Drs. Kong and von Aderkas. Crop information was available in the intended orchards and clones that had not produced to date, where available were targeted for testing.

Given the amount of seed needed from these orchards and the potential for improving production from cone induction, operational testing will indicate the impacts of induction techniques and timing for lodgepole pine without expanding into a broad based experiment. Past experience with this has been very successful with other species. In the future more intensive testing could be focussed on what has been learned from this trial.

Following discussions with Drs. Kong and von Aderkas regarding timing, data on past flowering was analysed in order to select clones that have either low or no history of past flowering. It was initially planned to conduct treatments in the Central Plateau (CP) orchards at Sorrento Seed Orchards and at Kettle River Seed Orchards only. Unfortunately there was a limited number of clones with sufficient ramets suitable for testing a full set of trees. This was also complicated by the fact that 2012 proved to be an excellent natural flowering year, thus reducing the number of clones further. It was decided to continue with the study by expanding it to include clones in the Bulkley Valley Orchard at Sorrento and the Prince George orchard at Kettle River. This allowed 10 clones to be selected at each Orchard Site. Fortunately three of the clones at each CP orchard were similar, allowing some clonal comparison between orchard sites.

Four treatment timings were applied according to the following schedule:

Sorrento	July 1	**Kettle River**	July 3
	July 18		July 19
	July 31		August 1
	August 15		August 14

A full set of controls were also selected for each clone. Treatments were applied using an alcohol-based solution at a rate of 40mg of GA 4/7 per drill hole site with the number of holes per tree being based on the diameter of the tree based on a schedule originally developed by Dr. Steve Ross and currently used with other species. Cone counts for 2012 and flowers for the current year were recorded. In the spring of 2013 flower counts will be done to determine the effectiveness of the treatments.

Figure 12: General size of trees treated.

6.2.5 Histological Study on Causes of Lodgepole Pine Seed Loss

Lisheng Kong and Patrick von Aderkas

A big increase in damaged seed was observed in BC MFLNRO seed orchard #307 (Kalamalka Seed Orchards, Vernon, BC), during August 2012 (Figure 14). The percentage of filled seed per cone (FSPC) diminished progressively over the course of the first two weeks, reaching levels under 50% FSPC, where it stayed until mid-September. On the basis of our data collection and analysis, percentage of filled seeds to total seeds per cone showed less variations than the average numbers of filled seeds per cone and thus could be used as a reliable indicator for seed loss.

Seed death occurred in two steps: death of the megagametophyte was followed by that of the embryo (Plate 53). Dying tissues ranged in colour from yellowish-brown to dark brown. Both gametophyte and sporophyte, *i.e.* embryo, were soft in texture, unlike their healthy counterparts, which were not only firm, but of much lighter hue. Histological study revealed three different types of tissue degeneration in megagametophytes and embryos. Healthy tissue (Plate 54A) was composed of storage cells that had abundant reserves of protein bodies, starch grains and lipid bodies. The cells were tightly appressed to one another. Megagametophyte prothallial cells were multinucleate, unlike embryos that were uninucleate. There were three types of tissue degeneration.

Type I) Tissue degeneration began with appearance of tiny intercellular spaces (Plate 54B). These spaces increased gradually in size and then the tissue developed large holes (Plate 54C). Fungal hyphae-like structures were frequently observed in cells as well as intercellular spaces (Plate 54D-F).

Type II) Degeneration had the appearance of cell liquidification. Cell walls were dissolved and cell contents were amorphously coagulated. Yellow particulate structures were frequently observed (Plate 54G, H).

Type III) Degeneration was progressive until only cell walls remained (Plate 55A-E). Protein body breakdown (Plate 55B) was followed by vacuolation and nuclear disintegration (Plate 55C). Tissue integrity failed with cells showing signs of cytoplasmic collapse and cell wall rupture (Plate 55D-E).

Types I and II occurred randomly at multiple loci in a megagametophyte. Different stages of Type I degeneration were sometimes present in the same tissue. Types I and II were found in samples from all collection dates (Table 11), whereas type III was observed in all dying megagametophytes that had softened tissue. These were sampled separately from others in August (Table 11). The ratio of other types of tissue degeneration, *i.e.* types I and II, showed little change before and after the large seed shortfall in August (Table 11). This could be due to an abiotic factor, such as high August temperature either alone or in combination with some other factor(s).

At the beginning of August, both megagametophytes and embryos had achieved their mature form. Embryogenesis was complete. Megagametophytes and embryos were filled with storage reserves in a manner typical of this species at this stage. Protein bodies, fat bodies and starch grains were abundant. Death of these mature normal-looking seed occurred sequentially. During the first two weeks, megagametophytes became soft, discoloured and unhealthy. As the megagametophytes continued to degenerate, the embryos showed signs of tissue failure. Prior to desiccation, embryo and megagametophyte showed holes, tears and tissue collapse. Eventually all tissues degenerated and shriveled, leaving only a dried remnant (Plate 55E).

A major reason for degeneration in seed was the presence of a fungus. The megagametophyte and embryo at the end of July showed less damage (Plate 54B), but as the weeks passed, more fungal-hyphae-like structures were found in the intercellular spaces (Plate 54D). Hyphae were widespread in holes that developed in the degenerating megagametophytes. We have been able to detect the fungus in early samples from middle of July; at this stage the hyphae are just beginning to spread. Our histological study does not support the possibility of *Leptoglossus occidentalis*-related seed loss. However, our study did not exclude the possibility of other organisms that might contribute to the seed fall. The presence of yellow particles found in many of the samples (Plate 54G-H) suggests the presence of an unidentified organism or an unknown (to us) aggregation phenomenon.

Conclusion

The seed shortfall in lodgepole pine is due to progressive degeneration of seed. The megagametophyte breaks down, followed by the embryo. There are different types of tissue degeneration. Tissue degeneration can occur in the absence or presence of a fungus, implying that there is more than one biotic or abiotic factor responsible for seed death. There is evidence of the presence of other organism(s), as uncharacterized yellow particles are commonly found in samples.

Overall, there is not one universal reason for seed failure, but there is good evidence for a fungal presence, and there is excellent evidence of tissue failure of the megagametophyte as the first and most important step. We suspect that high temperature in August may accelerate the process of seed degeneration.

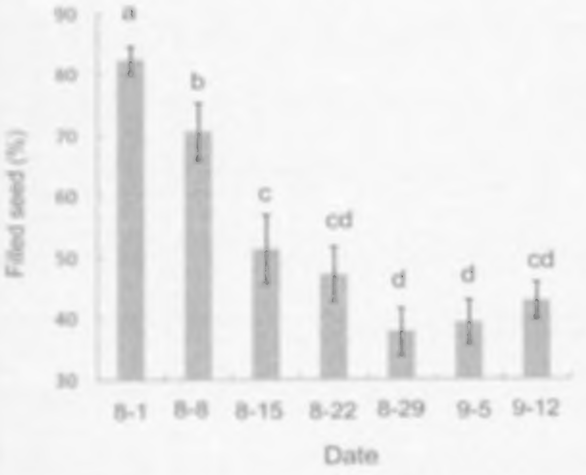


Figure 14. Percentage FSPC in lodgepole pine sampled late summer 2012. Mean ± SE, n=40 (letters indicate statistical significance (p<0.05) using Tukey's test).

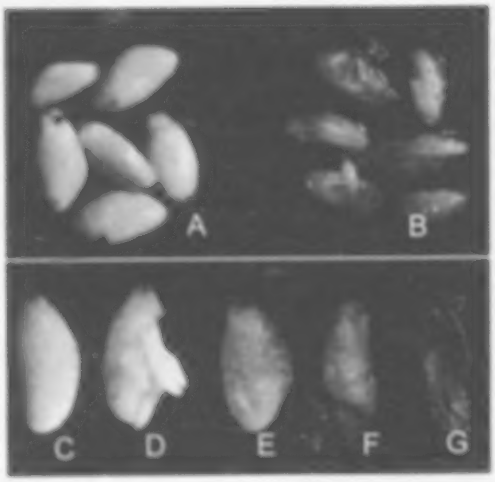


Plate 53. Comparison of normal and degenerating seed of lodgepole pine. A) normal megagametophtyes, B) degenerating megagametophtyes, C – G) progressive series of degeneration with C representing normal megagametophytes, D degenerating megagametophyte with intact and apparently healthy embryo, E-G shows final degeneration and desiccation.

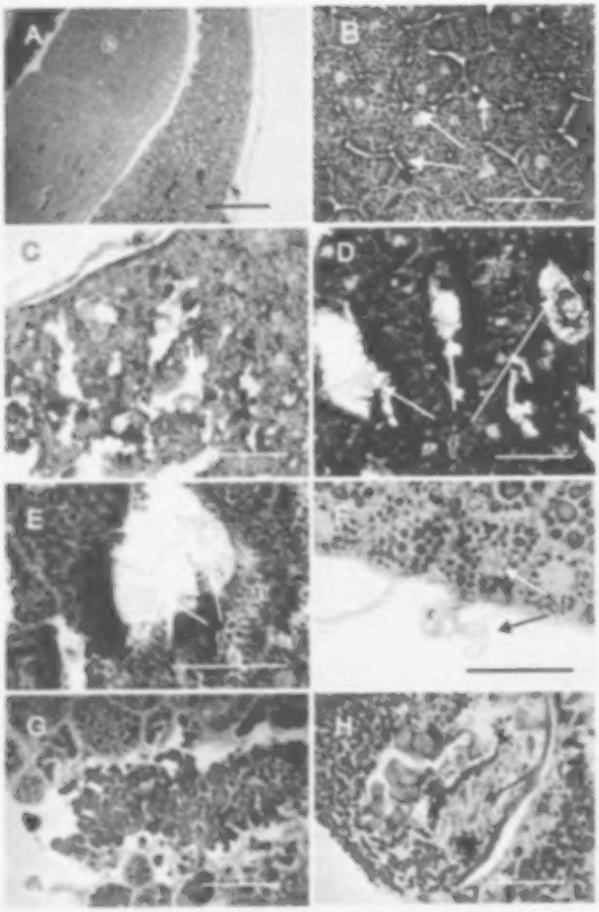


Plate 54. Fungal infection of lodgepole pine seed. A) healthy embryo and megagametophyte in early August, B) first stages of degeneration were marked by many intercellular spaces (arrows), C) megagametophyte tissue with large holes, D,E) fungal hyphae (arrows), F) Fungal hyphae in the cell and on megagametophyte surface, G) A single yellow particle in liquidized tissue, H) an aggregation of particles adjacent to a zone of severe degeneration (black arrow). e - embryo, m - megagametophyte, i - intercellular space, f - fungi. Scale bar in A = 200µm; all other bars = 50µm.

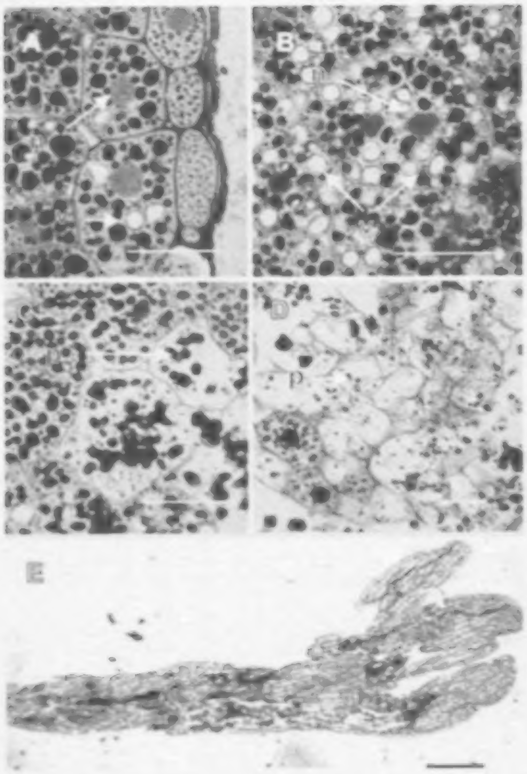


Plate 55. Breakdown of megagametophyte tissue and embryo. A) healthy megagametophyte cells have intact nuclei and protein bodies, B) megagametophyte cells with highly vacuole protein bodies, C & D) fusion of protein bodies (arrow) during cellular collapse, E) a dead embryo prior to desiccation in which cell walls but little else remain. n – nucleus, v – vacuole, p – protein body. Scale Bar E =250 µm; all other bars = 25 µm.

Tissue degeneration in Pli seeds (% total samples). Seed cones were collected from Kalamalka Seed Orchards, Vernon, BC in 2012.

Date	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug	15-Aug	22-Aug	29-Aug	5-Sep	12-Sep
Type I	75	73	71	79	77	83	90	89	95	98
Type II	37	43	40	57	50	44	53	56	57	57
Type III*	NA**	NA	NA	NA	100	100	100	100	NA	NA
Fungal hyphae	31	35	56	58	54	59	53	56	55	48
Samples (seed)	N=64	N=40	N=62	N=72	N=46	N=83	N=50	N=34	N=42	N=60

*Type III was only found in dying megagametophytes with obvious softened tissue (16-20 samples were examined from each time point in August); **NA: Not available.

Table 11. Tissue degeneration in Pli seeds (% total samples). Seed cones were collected from Kalamalka Research Station, Vernon, BC in 2012.

6.2.6 Methodology to Organize Operational Lodgepole Pine Cone Harvests by Using Observations of Seed Set Declines

Gary Giampa

The Problem

- Poor seed set in North Okanagan (NO) Pli orchards has been an issue for a number of years. We still do not know why this occurs.
- We need to average about 15 filled seeds per cone (FSPC) to meet our production goals.
- Pli orchards in Prince George (PG) have no trouble meeting FSPC production goals. PG production levels are the target for NO Pli seed orchards.

Filled Seed Per Cone

Comparing NO and PG results

- # of filled seed/# cones in sample.
- Data from 3 years of SPU0722 stats trial.
- FSPC measure *production*.

Orchard	2010 fspc	2011 fspc	2012 fspc	3 yr average fspc
Kal 307	6.2	8.8	7.3	7.4
VSOC 218	4.1	6.2	9.6	6.6
PG 228	22.9	23.6	20.1	22.2

Table 12. Filled Seeds Per Cone .

Per Cent Filled Seed Per Cone

Comparing NO and PG results

- # filled seed/# filled + empty seed in sample.
- Data from 3 years of SPU0722 stats trial.
- % filled seed measures *performance*.

Orchard	2010 %fspc	2011 %fspc	2012 %fspc	3 yr average %fspc
Kal 307	28.8	48.3	40.3	39.1
VSOC 218	25.3	34.3	45.3	34.9
PG 228	66.8	75.8	72.4	71.7

Table 13. Per Cent Filled Seeds Per Cone.

A point of interest – most conifer species perform poorly in the North Okanagan seed orchards. The other species are meeting seed needs so we are not too worried about them at this point. But, Pli is not the only poor performer!

Species	% full seed
Spruce	43.6
Lodgepole pine	55.6
Larch	56.4
Douglas-fir	56.8
Ponderosa pine	73.1

Table 14. % filled seed from 2012 operational collection samples.

What is the deal with the NO Pli?

- We usually harvest Pli through August into September.
- Data from recent harvest timing trials indicates that seed set declines dramatically in mid August.
- We are picking most of our crop after a high percentage of the filled seed has disappeared.
- This seed decline does not occur in Prince George.

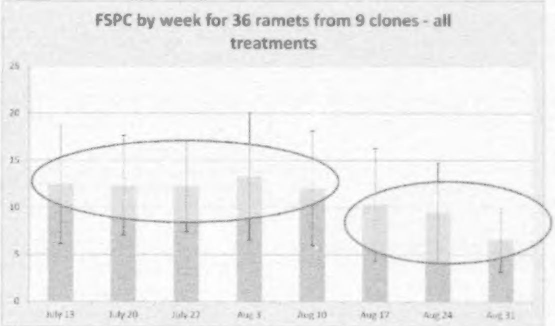


Figure 14. Note the dramatic loss of seed as the summer progresses!

So, why not just pick all the cones earlier?

Our harvest timing trial lots were germination tested and, unfortunately, seed quality suffered when the cones were collected too early

Germination in the NO did not reach acceptable (90% or better) rates until early August.

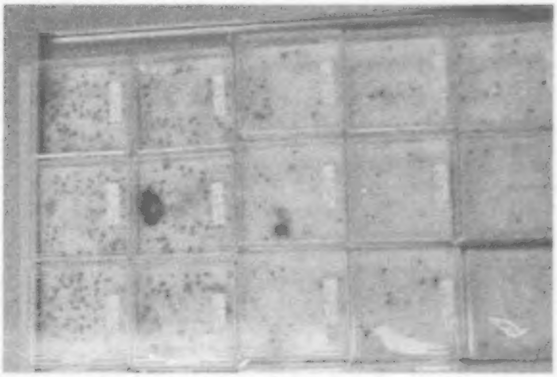


Plate 56. Pli seed from timing trial in germination test.

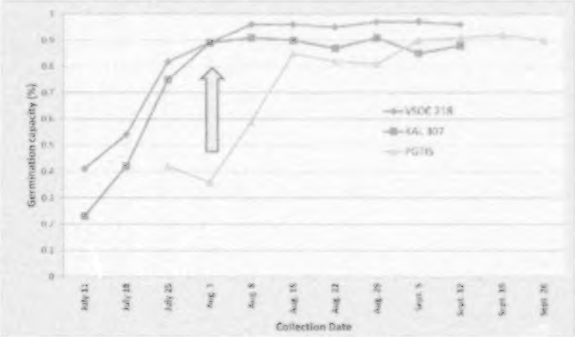


Figure 15. Germination in the NO did not reach acceptable (90% or better) rates until early August.

What do we know?

- Collection date has no impact on seed yield in PG, the present harvest schedule works up there.
- In the NO general seed yields remain at acceptable levels (+50% filled seed) until mid August.
- After mid August seed set declines rapidly.
- Seed quality does not meet acceptable levels until early August.
- That would give you about a 2 week window to pick a whole orchard. This would be very difficult to accomplish.

Harvesting the NO Pli orchards earlier than usual will not solve our seed delivery problems. Early collections will yield more filled seed, but, the seed does not germinate well.

- It appears that the NO is not the ideal location for Pli seed orchards.
- However, we have thousands of trees in the ground. So we need to find a way to make this work!

Initially we were discouraged by this outcome. However, there are a couple of interesting results hidden in the data which may present us with a chance to meet our goals.

- We collected clonal samples on a weekly basis and tracked % filled seed levels by collection period.
- We tied each collection period to a Growing Degree Day (GDD) figure collected on site.

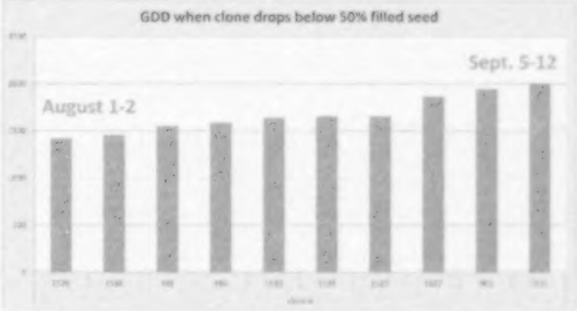


Figure 16. It appears that each clone starts its' seed decline at a different point.

What does this mean?

- Some clones "crash" early in the summer.
- Some clones hang in there until September.
- There is a "right" time to pick each clone (when seed germination is good but before seed decline reaches unacceptable levels). These windows of opportunity are very narrow, often only a few days.
- We can defer picking certain clones and concentrate on collecting those clones that lose seed early on.
- We can divide our orchard trees into collection groups, for instance – early, mid, late groups.

How does this help us?

- Dividing the orchard ramets into groups based on their decline in FSPC numbers allows us to organize our collections.
- This system allows us to concentrate on collecting clones when they contain the maximum numbers of viable seeds.

Plate 57. Pli is difficult to harvest and older orchards require the use of lifts

Clonal Harvest Timing Profile

- This is the term we use to describe each clone's seed decline schedule.
- For our harvesting system to work you need to know the seed decline profile for each major clone.
- This requires a bit of work, but will provide information that will make cone harvesting easier and more efficient in the future.

How to develop Clonal Harvest Timing Profiles

- Choose several ramets from each major orchard clone.
- Collect weekly samples starting in mid July and continuing until late August.
- Bulk samples by clone for every weekly collection period.
- Extract, x-ray and count filled and empty seed for each clone by collection period.
- The "crash point" will be obvious.
- Pick acceptable filled seed levels and tie to GDDs.
- Organize your clones into harvest groups (early, mid, late).

Another important use for harvest timing profiles

- They also can tell you when a "group" has lost seed to the point where you have to make a decision. Is it worthwhile to continue picking this group, or, should you move onto the next group before it starts losing seed?
- The profiles (tied to GDDs) tell you when to start picking a "group" of clones.
- We call this "the walk away point." If orchards can be picked before most clones reach this point, we should maximize their seed yields.

7.0 Applied Tree Improvement and Biotechnology

Yousry El-Kassaby

Long-Term Pollen Contamination in Douglas-fir Seed Orchards

Seed orchards are the conduit for genetic gain delivery to reforestation sites. Capturing the genetic gain attained through years of breeding, testing and selection is contingent on seed orchards acting as closed, perfect populations. While this sounds simple, closed perfect population means: 1) isolation from undesirable pollen and 2) attainment of reproductive synchrony (all parents participating in pollination at the same time) and equality (all parents contribute the same amount of pollen and seed). These requirements are impossible to attain as most orchards are placed within their respective species natural range, thus pollen contamination is unavoidable and the fact that fertility variation is a biological characteristic that cannot be avoided, yet it can be manipulated. Therefore, in reality seed orchardists work with a classical biological system that does not adhere to theoretical expectations.

Most of British Columbia seed orchards are effectively managed in spite of these "inadequacies" and substantial genetic gain is being captured and delivered in the form of genetically improved seedlings. The determination of seed crops' genetic worth is a prerequisite to their registration and utilization on BC's Crown land. A sophisticated and scientifically based rating system has been developed and implemented for assessing and rating seed crops' genetic worth and interestingly, the system is working after the determination of two essential parameters namely, parental contribution and rate of pollen contamination. The exact determination of pollen contamination can only be done with forensic approaches that utilize DNA fingerprinting and paternity assignment. Another alternative method to determine the extent of pollen contamination is the utilization of pollen traps as it is practical, less intrusive and least expensive; however, this method suffers from its imprecise nature. So, it was strategically determined to launch a long-term study using the forensic approach and, on average, annual pollen contamination fluctuation could be accounted for and the determination of a "general" estimate that encompass temporal variation could be used in future genetic worth assessment. Western Forest Product's low-elevation, second generation seed orchard was selected for this study and seed samples were collected from five years covering the range of pollen contamination around the Saanich Peninsula. To proceed with this work, all the seed orchard parental population was fingerprinted, thus the appearance of unknown genetic markers (alleles) can be detected and direct estimate of pollen contamination can be determined. The five seedlots used for this study were representative of 2005, 2007, 2008, 2009 and 2011 cone crop years. Seed from 2005 and 2009 were used by Ben Lai and Tony Kess, respectively, and they wrote their MSc theses on this topic. 2007 crop was studied by Jirka Korecky, a visiting graduate student from the Czech Republic (see Table 15 for results). The remaining two crops are being fingerprinted by Blaise Ratcliff (2008) and Jiayin Song (2011) and the results are expected to form Jiayin's MSc thesis. It is anticipated that this long-term study would provide the data needed for the development of the "general" contamination estimate needed for future years without the need for any further assessments.

Crop Year	2005	2007
Contamination	14.4%	18.5%
Selfing	15.2%	13.6%

Table 15. Pollen contamination estimates in Western Forest Products' Douglas-fir seed orchard.

8.0 Seed Orchard Pest Management

Jim Corrigan

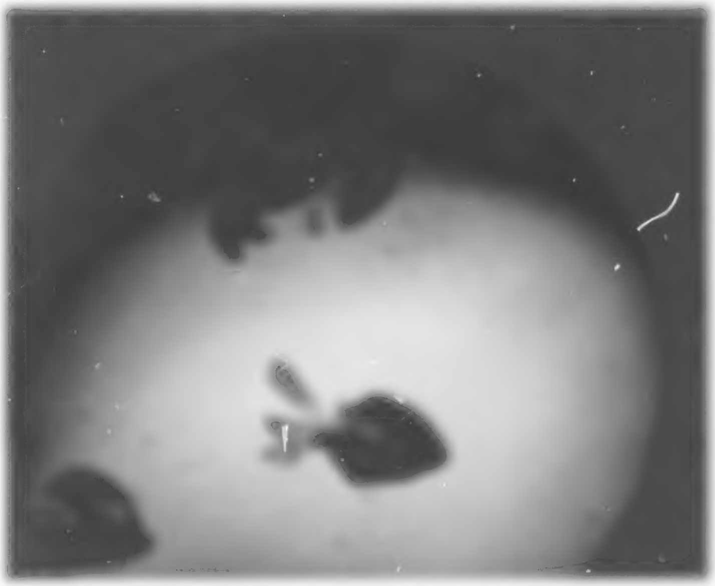
The objective of the Seed Orchard Pest Management Subprogram is to provide research, extension support and orchard-level pest management to increase yields of high quality seed coming from the seed orchards of our province. Research and extension activities are handled through the Tree Improvement Branch of the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). Dr. Ward Strong has a half-time responsibility to conduct pest management research, while Jim Corrigan delivers extension services to Interior and Coastal operations. Seed orchard personnel handle hands-on pest management duties at the orchard locations.

The Pest Management Technical Advisory Committee (PMTAC) manages annual Land Based Investment Strategy funding allocations that support relevant pest management research. Our Committee members come from the MFLNRO Tree Improvement Branch, the Canadian Forest Service, private & BC government seed orchards and the Forest Genetics Council. The PMTAC establishes research priorities and budgets through an annual process of proposal development and evaluation. In fiscal 2012, the PMTAC supported projects to: find new techniques to control Synanthedon pitch moths; assess novel pesticides for efficacy against several seed & cone pest species; determine if seed bug attacks can be detected on individual conifer seeds; support research initiatives on cone & seed pests; and support pest management extension activities around the province.

PMTAC Projects for fiscal 2012 are summarized in the Table 16.

Project	Species primarily impacted	Progress
Pesticide trials	Fd, Pw	Pesticide trials to identify new products to control *Contarinia oregonensis* and to support Federally-sponsored Minor Use trials targeting *Dioryctria abietivorella* and *Leptoglossus occidentalis*. Progress is being made to compile the data needed to register Delegate WG (spinetoram) for control of the fir coneworm, *Dioryctria abietivorella*, on Douglas-fir. Screening trials targeting the Douglas-fir cone gall midge, *Contarinia oregonensis*, may have found an effective product. Movento (spirotetramat) appeared to significantly reduce the number of *Contarinia* galls found in cones when observed during mid-season cone dissections.
The *Synanthedon sequoiae* pitch moth bole spray trial	Pli	Results from this trial failed to show that the pesticide Delegate, registered in Canada for use as a bole spray against Apple clearwing moth (*S. myopaeformis*), significantly reduced the number of *S. sequoiae* pitch moth attacks observed on the ramets used in this trial.
The *Synanthedon sequoiae* pitch moth attract and kill trial	Pli	Droplets that combined the sex pheromone for the Sequoia pitch moth, *S. sequoiae*, with a pesticide were applied in a grid inside lodgepole pine seed orchards. These treatments appeared to significantly reduce pitch moth attack rates at several Interior locations.
Detecting *Leptoglossus* seed bug feeding punctures on lodgepole pine seeds	Pli	Samples of lodgepole pine seeds that had been exposed to seed bug attack were put through several staining processes. We found that staining heated seeds in a cooled ruthenium red solution could be used to identify individual lodgepole seeds that have been attacked by seed bugs.
Support for operations of the research lab	All species	Funding was provided to support on-going lab operations and provide for technical assistance in support of pest management research activities.
Support for extension activities	All species	Funding provided for on-going extension support to Interior and Coastal seed orchard locations and to the Tree Seed Centre.

Table 16. Pest Management TAC projects for fiscal 2012.



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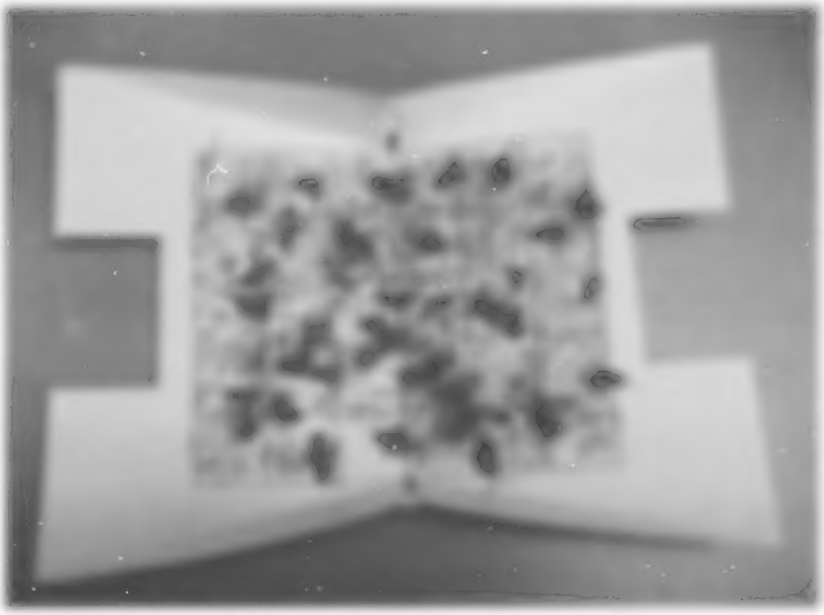

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Appendix 1 FGC Seed Planning Units

Seed planning unit (SPU)					Program category
#	Species	Common Name	SPZ	Elev. band (m)	
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Appendix 2 Tree Species

COMMON NAME	LATIN NAME	TREE SPECIES CODE
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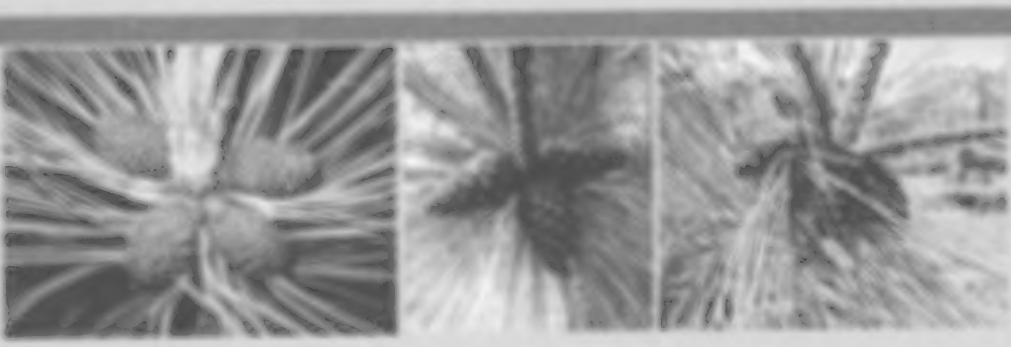

Ponderosa Pine (*Pinus ponderosa*)

BRITISH COLUMBIA
Ministry of
Forests, Lands and
Natural Resource Operations

FGC Forest Genetics Council
of British Columbia